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**AERONAUTICS IN REVIEW: AVIATION  
IN HISTORICAL PERSPECTIVE**

by James F. Connors  
Lewis Research Center  
Cleveland, Ohio

Presented to Lewis Aerospace Explorers,  
Cleveland, Ohio, September 30, 1967

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**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**



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James F. Connors\*

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The airplane has had a tremendous impact upon our society and our way of life. The world is smaller for it - people and nations are less isolated! Through high-speed transportation, previous obstacles of distance have been virtually eradicated. Most of us probably realize only vaguely the significance of the modern airplane. In 1966 alone, there were 58 certified American airlines carrying approximately 112,000,000 passengers and some 3 billion ton miles of freight. And today, the airplane is obviously a primary element in our national defense posture.

But how did all this come about? For full appreciation, we will do well to ponder the dramatic accomplishments that have taken place in manned powered flight and the attendant circumstances. What can we extract in the way of insight and perspective - the lessons of history?

Today, man has quite successfully penetrated the Earth's atmosphere and has ventured out into the infinity of space. With history going back many thousands of years, we must certainly be impressed by the extremely short time within which manned flight achievements have taken place. From his very origin and through all generations, man has dreamed of and aspired to a capability for sustained flight. Yet, from the first awkward steps of the Wright brothers in 1903 to our modern supersonic aircraft, it has only been about 65 years, or within the span of one man's lifetime. Viewed on a time scale,

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these achievements could well depict the "technological explosion" that is popularly referred to in current writings.

Here, we will only briefly touch upon technical highlights in the evolution of the airplane and flavor some of the major events in aviation history. Many excellent books and documentaries have been written in this area. Some (refs. 1 to 7) have been used as information sources. For convenience, a brief aviation chronology is included in appendix A.

Over the years, a truly prodigious number and variety of aircraft have been designed and built. Some historical airplanes employed by the United States Air Force (ref. 8) are shown in figure 1 in more or less chronological order. The modern stable of USAF aircraft (ref. 9) is illustrated in figure 2. These are but a small sampling! Many other configurations have been employed by the Air Force and the other services (notably the Navy) and in the commercial, business, and sports-flying fields.

As we view the total picture to establish a framework for the story of the airplane, it seems to breakout logically into phases or time periods:

Era of the Wright brothers

World War I

Late '20's and the '30's

World War II

Post-World War II; modern jet aircraft

The future; what lies ahead?

Especially in the military sense, speed has always been the prime measuring stick for aircraft performance. The Wright Flyer flew at about 30 mph; World War I aircraft averaged around 100 mph. In the late 1930's, bombers

operated at slightly above 200 mph with fighters at 300 to 350 mph. In 1945, bombers traveled at approximately 350 mph and fighters up to 550 mph as jets came into the picture. The Douglas "Skyrocket" D-558-II went 1238 mph in 1951, and the experimental North American rocket-powered X-15 (see fig. 2-15) reached a speed of 4104 mph in 1962 with Joe Walker as pilot. Such tremendous increases in flight speed did not come easily! Many difficult technical problems (or "barriers") had to be overcome. These occurred in all areas: structures (e.g., vibration, flutter, compressibility, etc.), aerodynamics, propulsion, materials, navigation, and control. We have also read about the "sonic" barrier and then the "thermal" barrier - both have long since been knocked down or hurdled.

During the evolution of the airplane, progress in aeronautics has received its impetus largely from the urgency of the military applications. Under the war influence, a great investment in resources was brought to bear on the research, design, and construction of progressively superior aircraft. Subsequently, the technology associated with advanced military airplanes was applied to new designs and adaptations for commercial purposes. The press of war was obviously a primary factor for the very rapid and dramatic strides made in aviation. With the military, their design requirements were best delineated in the slogan, "Higher, Faster, and Farther!" No sooner was one requirement met than another more stringent requirement set - with primarily Government-sponsored research leading the way to continual improvements.

Perhaps most of all, to attain its high levels of performance, aviation has required a team of dedicated, creative, imaginative, and courageous

people! This team includes the "gutty" knowledgeable experimental pilots; the ingenious designers, inventors, and fabricators; and the scientists and experimental researchers in the laboratory and wind tunnel. Many people with a great variety of specialized skills and technical disciplines have contributed heavily to the advancement of aeronautics. Whereas the Wright Flyer was largely the product of two minds, today's sophisticated airplane designs result from the contributions of many men, some now departed from the scene.

From its very inception, progress in aviation is probably best characterized as the product of research, or the application of the scientific method. This is the logic or the examination and reasoning process by which a particular problem or objective is approached. Stepwise, this involves the search and collection of available pertinent knowledge, the formulation of new hypotheses or theories, critical investigation and experimentation, and finally the formulation of acceptable conclusions leading to new or revised laws. With sound engineering judgments this approach translates into careful systematic study, isolation of variables to evaluate their individual effects, and extremely close attention to details. This is the fundamental research philosophy or method of inquiry! Note how it is threaded through the story of aviation. (Appendix B will be useful in defining some of the airplane terminology.)

### PRE-WRIGHT BROTHERS

The first documented description of a practical device for manned flight is traceable back to Leonardo da Vinci around 1500. This remarkable Renaissance man far ahead of his time produced detailed drawings of a helicopter, a parachute, and many flying machines. Unfortunately, these were

to be lost to the world for over 300 years. Leonardo and many to follow had a great fascination with birds. Much effort was expended in the study of ornithopters or flapping-wing devices. None, of course, ever paid off!

In 1766, the English chemist Henry Cavendish found that hydrogen was lighter than air and the concept of the balloon was introduced. However, it was with a heated-air system that the Montgolfier brothers made the first successful balloon flight in France in 1783. Interest in the balloons led to the subsequent development of the dirigibles. The death knolls, however, virtually sounded for lighter-than-air ships with the disasters to the "Shenandoah" in 1925 and to the impressive "Hindenburg" in 1937.

The real prelude to manned powered flight came with the so-called "glider school." The champion here was Germany's Otto Lilienthal (fig. 3). With his gliders, Lilienthal made more than 2000 flights over a 6-year period, traveling on some occasions more than 270 yards. His technique of shifting his body weight effected some measure of stability and control. In 1896, he died in a glider crash before he could complete previously laid plans for a powered flight using a carbonic-acid gas motor. A predecessor Sir George Cayley (1773-1857) was actually the first to assemble in theoretical form the many elements necessary for practical flight. His first model glider (1804) was accepted by some as the original airplane. Cayley concentrated on the aerodynamics; the importance of streamlining, movable tail surfaces, and the stabilizing effect of "dihedral." Another notable contributor among the glider enthusiasts was Octave Chanute, an American civil engineer. He introduced in a biplane glider a method of bracing the wings by struts and diagonal wires.

## ERA OF THE WRIGHT BROTHERS

The story of powered flight must certainly include Samuel Pierpont Langley, architect, astronomer, physicist, mathematician and, in later life, Secretary of the Smithsonian Institution. This esteemed scientist conducted many experiments in aerodynamics (e. g. , using his "whirling table" to simulate air speeds up to 70 mph). In 1896, he built and flew an unmanned steam-powered model (fig. 4), which he called an "aerodrome," for a distance of 3200 feet. Based on this, Langley received a government subsidy to construct a full-size man-carrying aerodrome. A most remarkable feature of this craft was the engine, built by Langley's assistant Charles M. Manly. A five-cylinder, four-cycle radial engine weighing only 125 pounds for 52.4 horsepower; far ahead of its time! An enormous publicity buildup preceded Langley's attempt at manned flight. The aerodrome resulted in failure in October, 1903. Professor Langley was thoroughly discredited and died heartbroken within a few years. The attendant ballyhoo in the public press and the subsequent ridicule had been too much for him.

During these same several years, the Wright brothers - Orville and Wilbur - had dedicated themselves to the task of achieving manned powered flight. In retrospect, their approach and concentration of energies differed from all others. They had recognized that the methods of construction for sustaining wings and of suitable power plants were in such advanced stages that both would be worked out satisfactorily. However, unlike the others, they felt that the real key to success was the development of a proper mechanism for stability and control of the craft. To this end, the Wrights focussed their attention during many glider and wind tunnel tests. They had at an early point discovered the most important principle of control - the aileron principle!

The Wrights did not have the formal training of the engineer. They owned and operated a bicycle shop in Dayton, Ohio. However, they were devoted experimentalists in their leisure time and read extensively all related publications. In their experimentation, they found the existing gas pressure tables in the literature to be in error and had to generate their own. The Wrights built their own wind tunnel (made out of starch boxes) and studied a great variety of wing shapes in a detailed systematic manner. They were true practitioners of the scientific method!

On the flat beach of Kitty Hawk, December 17, 1903, a little more than two months after Langley's failure, the Wright brothers achieved the first manned powered sustained flight. On the last flight of the day, Wilbur remained aloft for 59 seconds and traveled 852 feet. Their "Flyer" (figs. 1-1 and 5) was a biplane with a wing span of 40 feet 4 inches and weighed 605 pounds. Its two propellers were driven by bicycle-type gears and chains connected to the engine shaft. They built their own engine (13 horsepower, 180 pounds) and produced an aerodynamically efficient propeller. The main feature, however, was their method of control: warpable wings. Wires were attached to a cradle in which the operator lay. By swinging his hips and the cradle to the left, he tightened the cable attached to the outer strut of the starboard wing, warping the rear edge downward, whereupon increased air pressure would make the wing rise. At the same time, an auxiliary cable would give the opposite wing an up-warp that tended to lower it. This scheme transferred the control of the aircraft to the skill of the pilot. In later years, this method of control is to be supplanted by movable flaps or ailerons on the wing tips.

Invention and achievement did not bring the Wright brothers the sweet afterglow of success! In the wake of Langley's fiasco, public interest and reaction were very low. The Wrights, of course, were pressing to capitalize on their invention. However, it was not until December, 1907, that the U. S. Government (Army Signal Corps) first advertised for bids for an airplane. The Wrights' bid of \$25,000 was accepted. For the remainder of their years they were to be almost continually caught up in the stress of patent litigations. Glenn H. Curtiss had come into the picture and was the chief source of competition for the Wrights. Meanwhile, through shows, competitions, and demonstrations, interest in flying really caught on in Europe. Technical advancements were gradually incorporated into the airplane, particularly by Glenn Curtiss in his applications for the Navy. Elmer Sperry in this period also made significant contributions in the area of instrumentation.

## WORLD WAR I

At the onset of war in Europe (1914), France and Germany each had around 1500 aircraft. These were used initially for reconnaissance. It didn't take long, however, until aerial dueling started to occur with pilots using carbines, muskets, rifles, and even revolvers. Within 5 months the French began mounting machine guns on the upper wings of their light Nieuports (fig. 1-8).

In February, 1915, a Frenchman, Roland Garros, devised a way of firing a machine gun, mounted on the engine hood of his plane, straight ahead through the revolving propeller. The blades fitted with metal plates deflected about seven percent of the bullets; the rest passed through unobstructed. This type



of installation allowed the pilot to reload the gun in flight. This French technique took a heavy toll of German aircraft.

It wasn't long before the Germans countered with a more lethal invention of their own by Anthony H. G. Fokker. He devised a forward-firing machine gun synchronized to fire through the propeller without striking the blades. With this, German airplanes held mastery of the air. British pilots suffered many casualties and referred to themselves as "Fokker Fodder." Eventually, of course, the allies were able to reproduce the weapon for themselves and equalize the odds in combat.

Technological superiority in the design and arming of aircraft passed back and forth across the battle fronts of Europe. Whenever one side brought an improved plane to the front, the other side strove to equal or surpass it. Fokker's airplanes made rate of climb and maneuverability requisites for combat. Dogfights approximated hand-to-hand combat in the air.

When the United States entered the war in 1917, this country didn't have a single plane fit for combat. The War Production Board was set up to administer the manufacture of aircraft. A patent pool was established to expedite the military program. The Board's policy was to build only copies of foreign planes and equip them with American designed motors. This was principally the DeHaviland-4 shown in figure 1-7. In terms of airplane contributions to the war effort, the program was a rather dismal failure with much gross inefficiency in evidence.

American flyers, on the other hand, gave an extremely good accounting of themselves in combat. At the end of the war Rickenbacker's "Hat-in-the-Ring" squadron led all others with 69 confirmed victories. Rickenbacker himself (fig. 1-6) had destroyed 26 German planes in combat. Many other

U. S. heroes emerged from battle.

The importance of the airplane in warfare was a subject of enormous controversy at the close of World War I. Brigadier General Billy Mitchell became the leading proponent and standard bearer in a bitter campaign to recognize and establish air power. In 1921, through charges and demands by Mitchell, the military undertook experimental aerial bombardment of captured German naval vessels off Chesapeake Bay. This was to evaluate the potency of the airplane. A submarine, a destroyer, a cruiser, and the dreadnought "Ostfriesland" were sunk by Mitchell's bombers. His charges and demands became increasingly stronger and eventually forced his court-martial in 1925 for insubordination.

#### LATE '20's AND THE '30's

Upon the close of war in Europe, many fliers were returned to civilian life only to find general widespread public apathy towards the airplane. Little opportunity was available to earn a livelihood by flying or to initiate commercial flight ventures! Many took to barnstorming; demonstration and stunt flying at rural fairs all over the country. The Air Service, spurred by General Mitchell, took to establishing new transcontinental flight records and round-the-world exploits.

The Post Office was operating the air mail service with poor equipment and much hazard and hardship to the courageous men who flew. The passage of the Kelly Act by Congress in 1925 transferred the mail routes to private contractors. This provided fledgling air-transport companies the financial means for expansion into the great airlines of today. In October 1925, Henry Ford acquired the first air-mail routes with his winning bid and put into

service the Stout all-metal monoplane with three Wright Whirlwind engines. These were the largest commercial airplanes then produced.

In 1927 Charles A. Lindbergh (fig. 6) made the first nonstop solo flight across the Atlantic (New York to Paris). In his special Ryan monoplane "Spirit of St. Louis," he traveled 3610 miles in 33 hours, 32 minutes - about 122 mph. As a result of his great personal achievement, "Lindy" became the subject of public adulation (a national hero). Aviation was on the upswing!

In 1933 Wiley Post made his historic flight in a Lockheed Vega, the "Winnie Mae" (fig. 7). He set a record for a solo round-the-world flight of 15,596 miles in 7 days, 18 hours, 49.5 minutes. On this flight, he had an improved version of the Sperry Gyroscope automatic pilot and a radio directional device that registered on a dial the direction of the station to which the radio was tuned. Only 11 stops were made - a real demonstration of pilot stamina! The "Winnie Mae" was powered by a Pratt & Whitney 9-cylinder 425-horsepower Wasp engine.

In 1936, an outstanding milestone in airplane technology was reached when the DC-3 by Douglas Aircraft (fig. 1-37) made its debut. This plane had two 900-horsepower Wright Cyclone engines; weighed 24,000 pounds; and had a useful payload of 9,000 pounds - one-third greater than any plane that preceded it. The DC-3's 185 mph represented a 50-percent increase in cruise speed. In retrospect, the DC-3 over the years has been outstandingly profitable, preeminently safe, and fast for its time.

During the late 20's and the 30's, the National Air Races were firmly established. The best pilots competed annually for the most-coveted prizes;

the Thompson Trophy for the fastest in a closed-course pylon race and the Bendix Trophy for a transcontinental race. As an illustration, Jimmy Doolittle won the Thompson race in 1932 in a special Granville "Gee Bee" racer (fig. 8) with a 10-lap, 10-mile average speed of 252 mph. Other great pilots participated in these races, like Roscoe Turner, Harold Neumann, Jacqueline Cochran, etc. These races gave impetus to the development of the retractable landing gear, new fuels, and better engines.

In this time period, the amazing technological advances of aviation resulted largely from the superb cooperation between the industry and the government research laboratories. The work of the NACA (National Advisory Committee for Aeronautics) was particularly noteworthy!

In aerodynamics, the high drag of interplane struts on the biplane and the externally braced monoplane yielded significant advantages to the monoplane with thick wings braced internally in a cantilever construction. Between 1929 and 1934, more than 100 wing sections were tested in the wind tunnels of the NACA Langley laboratory. Of these, the famous NACA-23012 airfoil was widely used throughout the world. High wing loadings (i. e., high lift per unit area) were attained through the use of wing flaps and leading-edge slots. The guiding principle towards increasing aerodynamic efficiency was to reduce parasitic (or profile) drag. With this objective, NACA turned its attention to the powerplant and developed the NACA cowling in 1929. This device increased the economy of the airplane by approximately 10 percent simply by covering the knobby engine parts to streamline the nacelle, and by providing an ingenious ducting system for handling the required cooling air for the enclosed engine.

There were other developments such as standardization on the all-metal

monocoque or stressed-skin construction, which is a "single shell" fuselage wherein the skin and stiffeners bear most of the flight loads; improvements in the use of the supercharger to permit higher altitude capabilities; developments in radio for "instrument flying" and "blind landings"; and the introduction of the variable-pitch propeller. In the late 30's, aeronautical research facilities in England, France, Germany, and Italy were expanding rapidly. Europe was getting ready for war.

## WORLD WAR II

On September 28, 1938, President Roosevelt set the U.S. goals for air power and aircraft production; 10,000 combat airplanes annually. General Hap Arnold was in charge of military aviation. Mass production of aircraft was to be our first step against the threat of Fascist aggression. With this decision industrial miracles followed. In July, 1944, the AAF had 79,908 planes of all types. To avoid the costly technological errors of the first World War, aircraft manufacturers were made the prime contractors, and the automotive industry was drawn into production schemes as subcontractors. It fast became evident that this was to be a war of air power.

For the Americans, the war in the Far East was to begin with a demonstration of air power - the Japanese attack on Pearl Harbor. Throughout World War II many U. S. aircraft were to carry the brunt of battle - among them, notably, the B-17 "Flying Fortress" (fig. 1-28), B-29 "Superfortress" (fig. 1-43), P-47 "Thunderbolt" (fig. 1-35), P-38 "Lightning" (fig. 1-42), P-39 "Airacobra," P-40 Warhawk" (fig. 1-27), P-51 "Mustang" (fig. 1-38), B-24 "Liberators" (fig. 1-33), B-25 "Mitchell" (fig. 1-34), and the B-26 "Marauders" (fig. 1-41). In review, the tremendous U.S. mass-production

rate for aircraft was a major factor in deciding the war in favor of the allies.

In its pursuit of the war effort, the Americans took the view that the principal function of the airplane was bombardment. In Europe, the results of high-altitude precision pinpoint and saturation bombing proved to be the real turning point of the war. The remarkable Norden bombsight ensured success in daylight bombing from altitudes above the "flak" from antiaircraft fire. The B-17 "Flying Fortress" was first produced in 1939 and established international records for distance and weight carrying. It was not only fast but had a featherlike maneuverability and was astonishingly sturdy. Following a mission, it was not at all unusual to find a B-17 badly shot up and limping safely back to base.

To support the bombing missions, there was a need for long-range fighter escort. Not until July, 1943, did the P-47's attain a range of 340 miles. The P-38's in 1944 had a range of 585 miles. About the same time, the P-51 "Mustangs" were delivered. These planes were able to speed ahead of the bombers, clearing the skies of German aircraft for a distance of 850 miles. Round-the-clock air attack on Germany was the objective.

The P-51 "Mustang" (fig. 1-38), an outstanding combat performer during World War II, was largely a product of NACA research. Early tests in the Langley low-turbulence wind tunnel showed that considerable drag reductions were possible by controlling the pressure distribution over the wing. In 1940, the NACA's Annual Report to President Roosevelt included this one brief paragraph:

"Discovery during the past year of a new principle in airplane-wing design may prove to be of great importance. The transition from laminar to turbulent flow over a wing was so delayed as to reduce the

profile drag, or basic air resistance, by approximately two-thirds.

It is too early to appraise adequately the significance of this achievement. So far, its application is limited to small airplanes, but there are indications of its ultimate applicability to larger airplanes through continued research. It should increase the range and greatly improve the economy of airplane operation."

This new principle was applied to the wing design of the Mustang airplane. The P-51 was subjected to other aerodynamic cleanup studies and remedies by NACA. The results are now history. In both speed and range, the P-51 was the outstanding propeller-driven fighter of this period.

In the bomber class, the successor of the B-17 was the famous B-29, or Boeing "Superfortress." First flown in July, 1943, this airplane brought about the defeat of Japan. A four-engine bomber, the B-29's engines produced 2200 horsepower each, compared to 750 in the B-17. Takeoff weight was 120,000 pounds - almost twice that of the B-17. With a wing span of more than 140 feet and a pressurized cabin, the B-29 could be flown with comfort at 35,000 feet. It had an operational radius of 2300 miles with a 10,000-pound payload. In 1945, of course, it was the B-29 that carried the atomic bomb to Hiroshima and brought about the end of the war.

During the latter stages of the war, the jet airplane began to emerge. Bell Aircraft produced the YP-59 "Airacomet" in 1943, the first jet fighter in America. This plane utilized the turbojet engine researched and developed by Frank Whittle in England. Actually, the Germans had been busy too and had put into operation in the preceding year the Messerschmitt-262 fighter. For a given thrust level, the turbojet engine is smaller, lighter, and simpler in

design than the reciprocating engine. However, it also has a higher fuel consumption. Propulsive efficiency of the jet engine increases with speed, whereas with a propeller, compressibility losses (associated with high-speed airflow over a lifting surface) would cause performance to fall off drastically. Introduction of the jet engine thus opens up still higher ranges of aircraft speed.

### POST-WORLD WAR II - MODERN JET AIRCRAFT

One of the successors to the B-29 bomber was the Strategic Air Command's B-36 built by Convair (figs. 1-40 and 9). This was the largest airplane to enter the Air Force inventory. It had a wing span of 230 feet and a length of 162 feet. Its gross weight on takeoff was 358,000 pounds compared to 135,000 pounds for the B-29. With a nominal range of 10,000 miles, the B-36 is powered by six propeller engines and four turbojet engines. It is expensive; \$3,500,000 compared to \$640,000 for the B-29. Its speed was about 435 mph. For further size comparison, the original Wright Flyer is sketched on the photograph in figure 9 illustrating again the dramatic evolution of the airplane.

Presently, the B-36 has been superseded by the B-52 "Stratofortress" (fig. 2-2). The Boeing B-52 is powered by eight Pratt & Whitney J-57 Turbo-Wasp engines, each with a thrust rating of 9400 pounds. It is SAC's primary heavy bomber and carries two HOUND DOG air-to-surface missiles. In 1957 with in-flight refueling, the B-52 flew 24,325 miles in 45 hours, an average of 540 mph. Presently, the role of the long-range high-speed bomber is being challenged by the application of rocket-powered guided missiles, such as ICBM's.

The Century series jet fighters are illustrated in figures 2-4 to 2-9. These planes, of course, are highly sophisticated aerodynamically and are



electronically complicated. All generally have transonic or supersonic dash capability. In contrast with World War I flyers, today's combat pilots must be highly trained technically and are more dependent on systems' performance than individual flying skills. This is obviously a consequence of the tremendous speeds that preclude human observations and determinations in flight. Electronic systems for navigation, control, weapons firing, etc. must necessarily predominate. One look into the pilot's compartment of a modern jet will quickly corroborate this!

In 1960, Russia announced that a U. S. aircraft had been shot down over Soviet territory as it was attempting a photo-reconnaissance mission. The airplane was the Lockheed U-2 (fig. 10). This plane is of interest here because the U-2 was designed for a very special and specific purpose. Originally it was to be used by NASA for weather research and high-altitude radiation sampling. The design objective was to achieve maximum possible altitude performance within the state of the art. This performance was obtained by using a sailplane-type wing, keeping structural weight and strength very low, and by using a specially designed high-altitude version of the Pratt & Whitney J-57 engine with low-volatility fuel. An example of U-2 weight savings is the single main landing gear. Small jettisonable wheels keep wings level during takeoff roll. The U-2 is able to maintain level flight at altitudes above 70,000 feet with a range of 3000 miles or more. This aircraft illustrates the practical tradeoffs and compromises available to the designer to meet particular specifications. Another case where speed was the uppermost consideration was the "Gee Bee" racer shown in figure 8. This plane was practically all engine; everything else was minimized. In World War II, speed of American planes was sacrificed

by requirements for electronic navigation packages and personnel armor protection. The aircraft designer must balance all these requirements as he searches for an optimum.

The F-111A (fig. 2-14) is another novel approach. With its variable-geometry wings that can be extended in flight for takeoff, landing, and subsonic speeds and then swept back sharply for supersonic operations, the F-111 is designed as a multipurpose aircraft. It can be used for counter-air, interdiction, close air support of ground forces, and reconnaissance. Its design Mach number is about 2.5 (i. e. , a speed 2.5 times the speed of sound). Presently, this airplane is in the development phase.

To meet its responsibility --- "to supervise and direct the scientific study of the problems of flight, with a view of their practical solution" ---, the NACA/NASA joined with the Air Force, Navy, and the industry in building and flying a number of advanced high-speed research airplanes (figs. 11 and 2-15). The program has been essentially completed with tremendous success. The first supersonic flight was achieved by Charles Yeager on October 14, 1947, in the Bell X-1. In 1951, William Bridgeman flew the Douglas D-558-II at Mach 1.89, and in 1953, Yeager took the Bell X-1A to Mach 2.5 - 1650 mph. Planes flown by service and civilian pilots pushed both speed and altitude records steadily higher; by June, 1962, test flights of the North American X-15 rocket plane had taken the heat-resistant craft to an altitude of 250,000 feet (about 47 miles) - and a speed of Mach 6.04 (4093 mph). Each X-15 flight has furnished important design data for high-altitude hypersonic operational aircraft. The practicability of pilot-controlled entry into the atmosphere has been demonstrated and a great amount of data on physiological and psychological reactions of man to space flight has been provided.

### THE FUTURE; WHAT LIES AHEAD?

As we look down the road, we can only see further rapid expansion in the field of aeronautics - particularly in the civilian commercial sector. In the immediate offing, we find the large subsonic Jumbo Jets and the Supersonic Transports. Both are presently in various stages of research and development.

In the large subsonic airplane category, Lockheed (Marietta, Georgia) is working on the C-5A. This airplane will have a gross takeoff weight of 728,000 pounds, a wing span of 223 feet, and a 65-foot-high tail. It is being designed to move 110 tons (or 500 to 600 passengers) 3000 miles in 7 hours. Power for this job will be supplied by four TF-39 turbofan jet engines by the General Electric Company, each developing 41,000 pounds of thrust. This fan engine is expected to have a specific fuel consumption one-quarter less than that for a standard turbojet. This type of airplane will offer large scale economic transportation in both the passenger and cargo markets.

The commercial supersonic transport is more of a challenge. The British and the French are developing the Concorde for application at approximately Mach 2. The U. S. has prototypes of a supersonic transport (SST) now being developed by the Boeing Company. In May, 1967, a contract for the construction of two prototypes was signed. The Boeing SST (fig. 12) will have variable-sweepback wings, an overall length of 306 feet, 9000 square feet of wing area, and a maximum takeoff weight of 675,000 pounds. It will carry 250 to 350 passengers at a Mach number of 2.7 (or 1800 mph) and at a cruising altitude of 64,000 feet. With 313 passengers it will have a range of over 4,000 miles. Most of the SST airplane will be built of an alloy of 90 percent titanium, 6 percent aluminum, and 4 percent vanadium. The plane must climb rapidly after

takeoff and then approach at low engine power settings to minimize the noise at airport communities. At supersonic cruise speeds, a severe aerodynamic design problem - sonic boom - must be resolved before regular commercial flights over populated areas can be tolerated.

Another general area of special interest to the aeronautics program is V/STOL (Vertical and Short TakeOff and Landing) aircraft. Particularly in the military situation (Viet Nam), the utility of the helicopter has been quite successful. Some are illustrated in figures 2-23 to 2-25. A great variety of other V/STOL configurations are under active study. With tomorrow's mushrooming populations, the megalopolitan areas will have an acute need for relatively short high-speed transportation. V/STOL aircraft may pose an attractive and practical solution. However, much research and development work remains.

In closing, I quote directly Dr. Hugh L. Dryden:

"Aeronautical technology --- has exploited the power of organized effort, learning to draw on all the resources of science, and to synthesize and integrate the effort of men of many disciplines and skills."

The future looks even more promising!

### APPENDIX A: AN AVIATION CHRONOLOGY IN BRIEF

- 1903 Langley's "Aerodrome" with Charles Manly as pilot fails in its second attempt to fly and plunges into the Potomac River. Six days later on December 14, Wilbur Wright travels about 40 feet in 3.5 seconds. On December 17, the Wright Flyer goes 852 feet in 59 seconds at Kitty Hawk, North Carolina. The first manned, powered airplane!
- 1906 Santos Dumont (France) makes first airplane flight in Europe ("14 - bis" for 8 seconds).
- 1908 Lt. Selfridge is first U. S. military man to fly "heavier-than-air" machine. Glenn Curtiss pilots "June Bug" 1 kilometer before official witnesses. First airplane owned by U. S. Army is Wright biplane. In France, Henri Farman went up with a passenger (Delagrange) for 150-foot hop. First passenger-carrying flight!
- 1909 Glenn H. Curtiss Manufacturing Co., The Wright Co., and the Glenn L. Martin Co. are established. The first airplane flight across the English Channel is made by L. Bleriot in his "Number XI."
- 1910 A Curtiss biplane, piloted by Eugene Ely, took off from land and flew out to a platform on the cruiser "Pennsylvania." This forms basis for concept of a naval aircraft carrier. Shortly afterward, Captain I. Chambers, USN, developed compressed-air catapult for launch from ship board.
- 1911 Curtiss is recognized for his invention and successful demonstration of the hydroplane - the Triad - a seaplane equipped with retractable wheels for ground landing. First airplane is delivered to the American

- Navy. First air mail in U. S. is carried aloft by Earle Ovington on Long Island.
- 1912 The first fighter plane is single-seat Farnborough B.S. 1, designed by deHavilland.
- 1913 Elmer Sperry demonstrates his gyroscopic stabilizer to the Navy. Sikorsky designs first multiengined airplane, the four-engined biplane "Bolshe."
- 1914 Sperry invents optical-type drift indicator, automatic pilot, and gyroscopic compass.
- 1915 The NACA is established by act of Congress. The first fighter with a fixed, forward-firing machine gun, Anthony Fokker's Eindecker Scout. The gun was synchronized to fire through the whirling propeller. Junkers designs first cantilever wing, low-wing, all-metal airplane - the J-1 monoplane.
- 1916 World altitude record set by V. Carlstrom in a twin-engined "JN" Curtiss - 16,500 feet.
- 1917 With U.S. at war in Germany, U.S. is asked to send 4500 planes with personnel and supplies for 1918 campaign. McCook Field, Dayton, Ohio, established as the Air Service Experimental Base.
- 1918 Army operates regular air-mail service between Washington and New York City. First NC-1 flying boat is successfully flown.
- 1919 Development of leak-proof tanks, free parachute back-pack, reversible- and variable-pitch propellers, syphon gasoline pump, fins and floats for emergency water landings, and the turbocompressor or supercharger developed by Dr. Sanford Moss of General Electric. Lt. Commander A. C. Read and five-man crew fly a Curtiss NC-4 Navy

flying boat in the first airplane crossing of the Atlantic (N. Y. to Lisbon via Newfoundland and the Azores). First nonstop crossing by Captain Alcock and Lt. Whitten-Brown in a Vickers Vimy from Newfoundland to Ireland (16 hours, 12 minutes averaging about 119 mph).

- 1921 As an outgrowth of charges by Brig. Gen. Billy Mitchell, the military undertakes experimental aerial bombardment of captured German vessels in Chesapeake Bay. Submarine, destroyer, cruiser, and dreadnought "Ostfriesland" sunk.
- 1922 World speed record of 223 mph set by Billy Mitchell in Curtiss racer. Wing-type radiator developed by Curtiss.
- 1923 First refueling in midair between two airplanes. DeBothezat helicopter achieves sustained flight at an altitude of 15 feet for 2 minutes, 45 seconds. World speed record set at 267 mph in Curtiss Racer.
- 1924 First aerial circumnavigation of the globe! Four Army Douglas biplanes leave Seattle and two return after covering 26,345 miles in an elapsed time of 175 days.
- 1925 Oleo landing gear tested for Navy on N8-1 airplane. Introduction of Ford trimotor, an all-metal monoplane designed by William A. Stout with 400 horsepower Liberty engines, first production airplane. Billy Mitchell found guilty in court martial. Cleveland opens its \$1,000,000 municipal airport which covers 1000 acres.
- 1926 First Pratt & Whitney "Wasp" engine, a nine-cylinder radial air-cooled engine, 400 horsepower at 1800 revolutions per minute.

Lt. Comdr. R. Byrd and Floyd Bennett fly over the North Pole in a trimotored Fokker.

- 1927 Lindbergh makes first nonstop solo flight across Atlantic (N. Y. to Paris), Ryan monoplane "Spirit of St. Louis," 3610 miles in 33 hours, 32 minutes, about 122 mph.
- 1928 Young English Air Cadet Frank Whittle published a paper predicting application of jet propulsion to high speed aircraft.
- 1929 Doolittle makes first flight relying entirely on instruments. Major Spaatz sets refueling endurance record in Fokker Army transport "Question Mark" - 150 hours, 40 minutes, 15 seconds. Development of NACA cowling.
- 1932 Doolittle flies his "Gee Bee" over 100-mile course of Thompson Trophy Race at average speed of 253 mph. New developments are a control mechanism for controllable pitch props and a liquidometer for displaying the condition of all fuel tanks on the airplane.
- 1933 Westbound transcontinental record of 11 hours, 30 minutes established by Col. Roscoe Turner in Wasp powered Wedell-Williams monoplane (Bendix Race, N. Y. to L. A.). Wiley Post in the "Winnie Mae," a Lockheed Vega, sets record for solo around-the-world flight (15,596 miles in 7 days, 18 hours, 49.5 minutes). Wedell breaks speed record for landplanes with 305.33 mph. Boeing builds 75, Model 247-D, all-metal transports for airlines and P-26-A pursuit planes for Army. Retractable landing gears are introduced with a new radio compass.



- 1935      Howard Hughes sets new landplane speed record of 352.39 mph in his "Special." Douglas Aircraft produces first of famous DC-3 transports. Device for elimination of propeller ice is introduced.
- 1936      Pratt & Whitney develops new 1160-horsepower 14-cylinder twin-row Wasp engine. Whittle begins experiments on gas turbine engine.
- 1937      Hughes flies from Los Angeles to New York in 7 hours, 28 minutes, 25 seconds for average of 327.5 mph. Dirigible "Hindenberg," filled with hydrogen, crashed and burned - beginning of end for rigid-airship transportation!
- 1938      Supermarine Spitfire fighter (low-wing single-seater) goes into production in England.
- 1939      B-17 Flying Fortress goes into production. Bell builds P-39 "Airacobra" with deadly nose cannon for Army. Heinkel He 178 (first jet plane) flown successfully in Germany - little interest in it for military purposes.
- 1940      Commercial airlines of U. S. complete full year without a fatal or serious accident. Puncture-proof gasoline tanks tested at Wright Field. Boeing 307-B "Stratoliner," first supercharged pressurized-cabin airplane, introduced.
- 1941      First successful true "flying wing" by Northrup is announced by Army. Jet-powered Gloster plane powered by a Whittle-I jet engine built and flown on May 14. The 650-pound Whittle engine produced more thrust than a comparable Rolls-Royce reciprocating engine that weighed 1650 pounds.

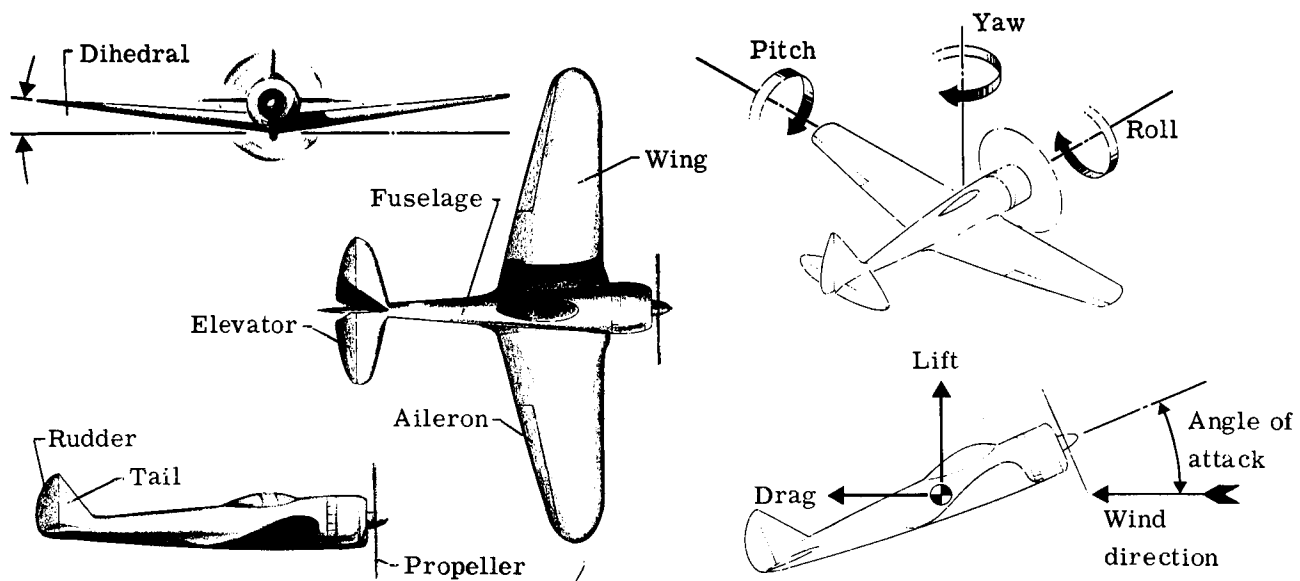
- 1942 Doolittle leads his B-25 "Mitchell" bombers in raid against Japanese mainland after taking off from carrier "Hornet." Total of 47,836 military aircraft produced this year. First operational military jet, the Messerschmitt 262 fighter, is tested in Germany.
- 1943 Water-injection used for power augmentation in fighters. Bell Aircraft produces YP-59 "Airacomet" first jet fighter in America.
- 1944 USAAF peaks at 2,383,000 men and 64,591 planes. Germany puts first rocket-propelled airplane into operation - Messerschmitt 163 Komet.
- 1945 B-29 drops atomic bomb on Hiroshima, Japan.
- 1947 Mantz wins Bendix classic (2045 miles in P-51 "Mustang" at 460.4 mph). Allison liquid-cooled V-1710-G6 engine rated at 2250 horsepower. Its new jet engine is rated at 7500 horsepower at 600 mph. Lockheed P-80R sets speed mark at 623.3 mph. Douglas D-558 "Skystreak" goes 650 mph. The first manned aircraft to exceed speed of sound flown by C. Yeager (Bell X-1, speed Mach 1.06 or 670 mph). A separate air force is established as a co-equal partner with the Army and Navy - the realization of Billy Mitchell's dream.
- 1948 Wright Aeronautical announces new 18-cylinder air-cooled engine rated at 2700 horsepower (R3350-26-W Cyclone). F-86 "Sabrejet" goes 671 mph with Major R. L. Johnson. Vickers Viscount (with turboprop engines) goes into airline service.
- 1949 Douglas D-558-II hits speed of 710 mph at 26,000 feet.
- 1951 D-558-II goes 1238 mph at 79,494 feet.

- 1952 Convair's XF2Y-1 "Sea Dart," first combat-type airplane to employ hydroskis, makes its debut in San Diego. With the Air Force and NACA, Bell investigates variable-sweep wings on the X-5.
- 1954 Boeing-707 is tested; 550 mph, range 3500 miles, capacity 150 passengers.
- 1959 North American X-15 is built for hypersonic flight, eventually to approach Mach 7.
- 1962 X-15A with Joe Walker as pilot reached 4104 mph. Major White climbed to 314,750 feet altitude in the X-15A.
- 1963 Lt. Col. Rushworth attained Mach 6.06 in the X-15A - skin temperatures above 1300<sup>0</sup> F. The B-58 Hustler made the longest supersonic flight in history (nonstop from Tokyo to London in 8 hours, 35 minutes for an average speed of 938 mph).
- 1964 First test flight of the F-111A (TFX) variable-sweep-wings tactical fighter, designed for maximum speed of Mach 2.5. Announcement of the Lockheed A-11 or USAF YF-12A, a Mach 3 prototype fighter.
- 1965 The design cruising speed of Mach 3 was attained for the first time by the XB-70A Valkyrie strategic bomber (by North American) on its 17th flight, October 15.
- 1966 President Johnson in his message to Congress proposed a joint Government-industry program to build the prototype of a safe and and commercially profitable supersonic airplane. He requested an additional \$200 million to initiate the program (\$231 million has already been appropriated).

## APPENDIX B

## AIRPLANE COMPONENTS AND TERMINOLOGY

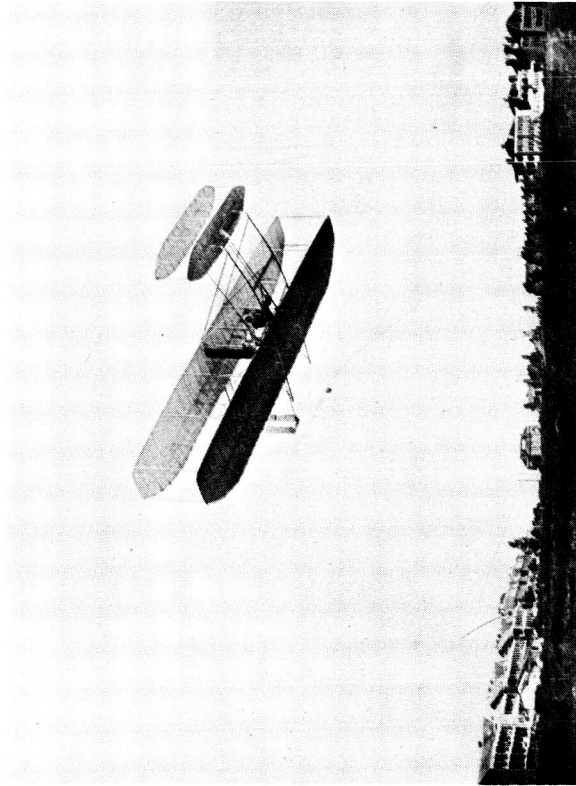
The components of an airplane and the terminology used are defined in the following sketches:



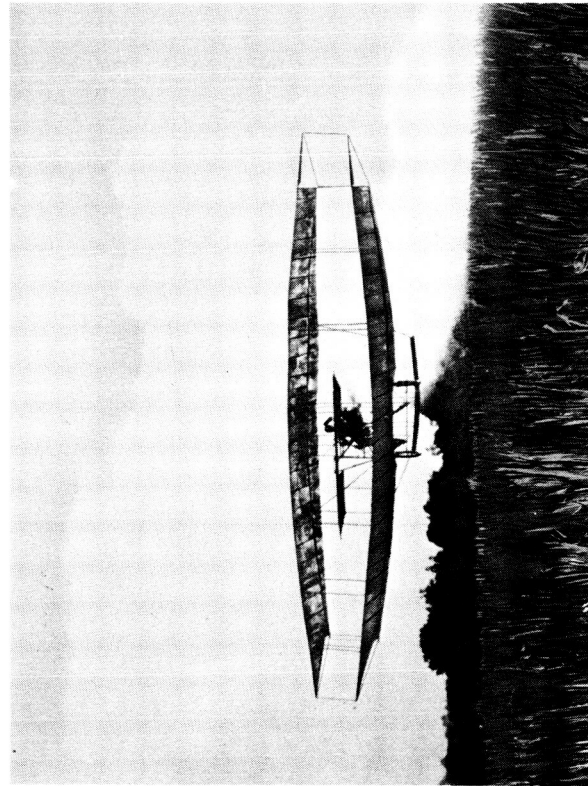
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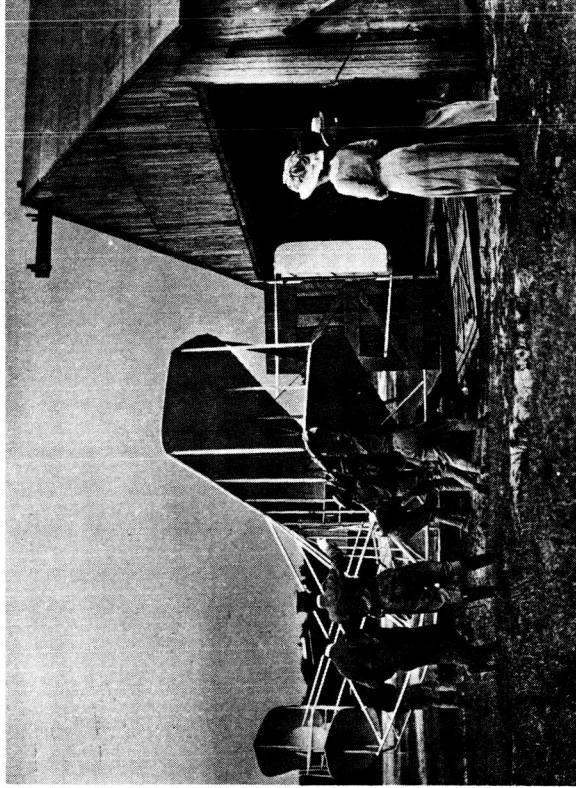
**Figure 1. - USAF historical aircraft; Wright Flyer to Lockheed P-80  
Shooting Star. (Shown in photographs I-1 to I-45.)**



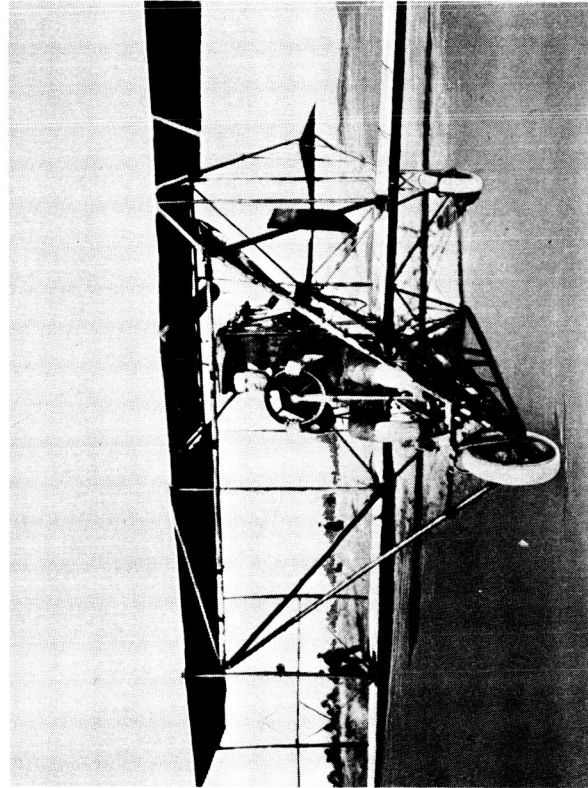
I-1. ORVILLE WRIGHT circles Fort Myer, Va., during tests conducted for the War Department, in 1908. During these tests, he made the world's first flight of longer than one hour.



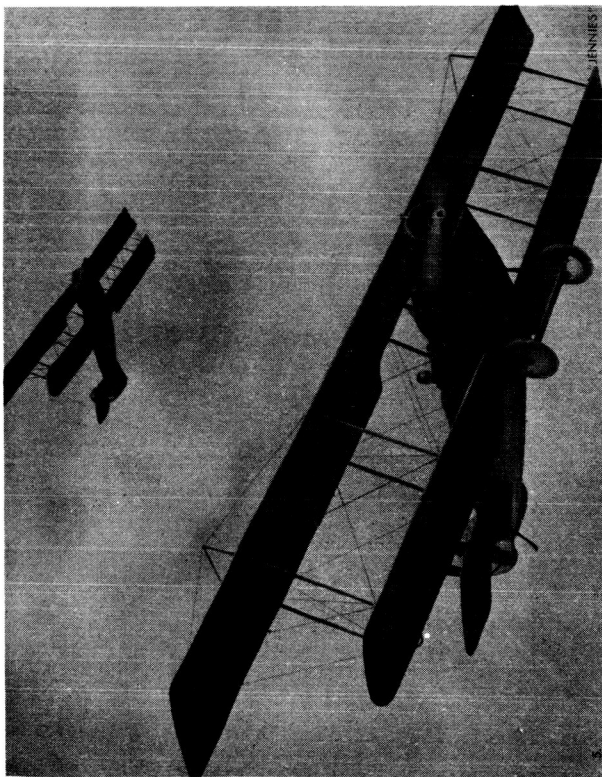
I-3. GLENN CURTISS scored a dusty triumph when his "June Bug" made a 6,000-foot flight in 1908.



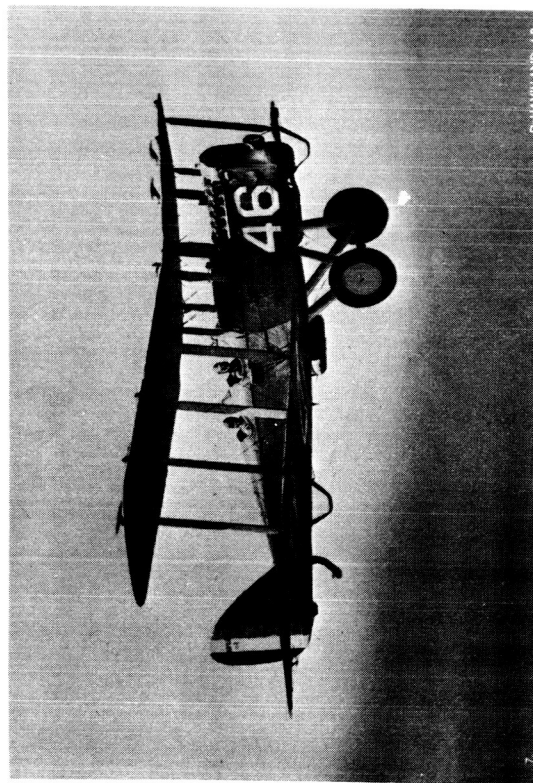
I-2. WILBUR WRIGHT's aeroplane is moved into a "hangar" while curious military and civilian spectators watch.



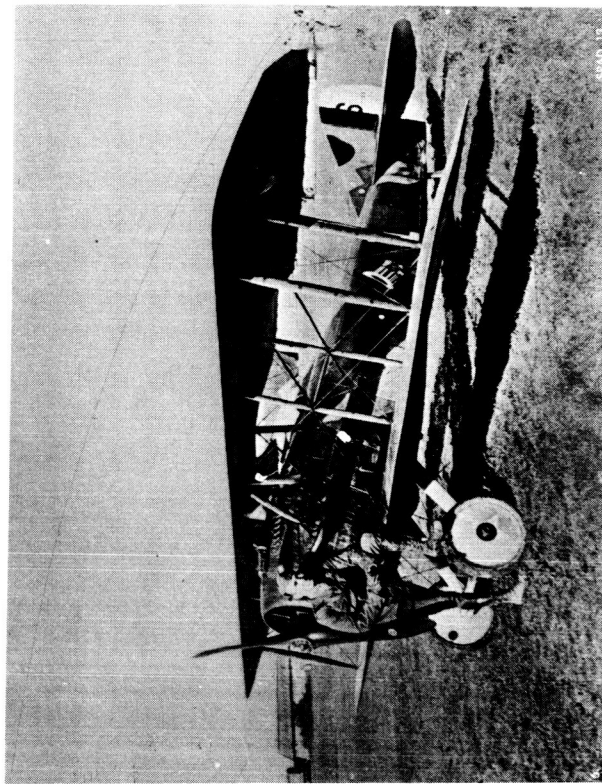
I-4. EARLY U. S. AVIATOR prepares for a flight in a Curtiss military airplane in 1913. Powered by a four-cylinder engine mounted behind the pilot, these pusher-type airplanes proved too dangerous and were not accepted by the War Department after 1914.



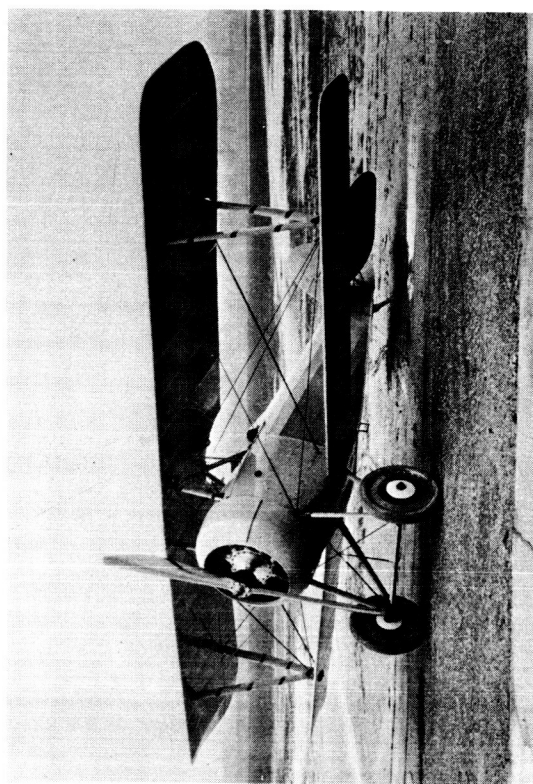
I-5. WORLD WAR I CURTISS JN-4s in formation. Although thousands of these airplanes were built during the war years, none took part in the air battles over France and Germany. Affectionately known as the "Jenny," this plane, flown by a generation of pilots, was the mainstay of the early "barnstorming" era.



I-7. THE DEHAVILLAND 4-B, post-war American modification of British-designed DeHavilland 4 which had been mass-produced in the United States for use during World War I. American pilots used the original DeHavilland 4 for observation and bombing missions during 1918.

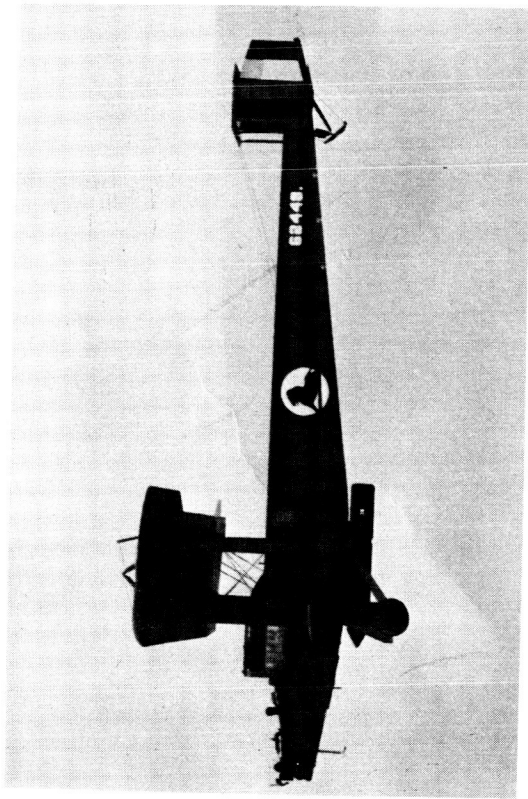


I-6. U. S. ACE OF ACES, Capt. Eddie Rickenbacker, with his famous Hat-in-Ring Spad 13 of World War I fame. The Spad, one of the finest fighting machines developed during World War I, was the favorite airplane of American pilots. Built by the French, 893 of these machines were purchased by the United States.

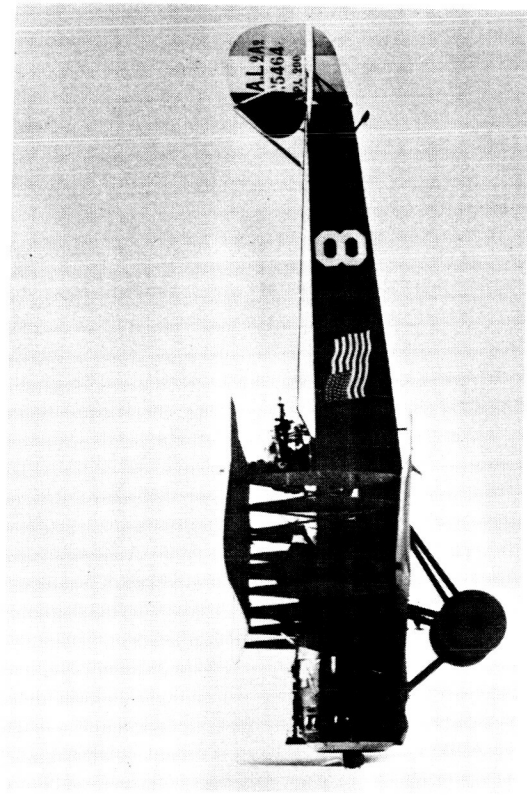


I-8. THE NIEUPOORT 27, built by the French, was flown by many American pilots during World War I. Although it had the uncomfortable habit of shedding fabric from its top wing, many top-ranking aces built up their scores in this highly maneuverable little pursuit. This was the plane that Capt. Eddie Rickenbacker used in starting his string of victories.

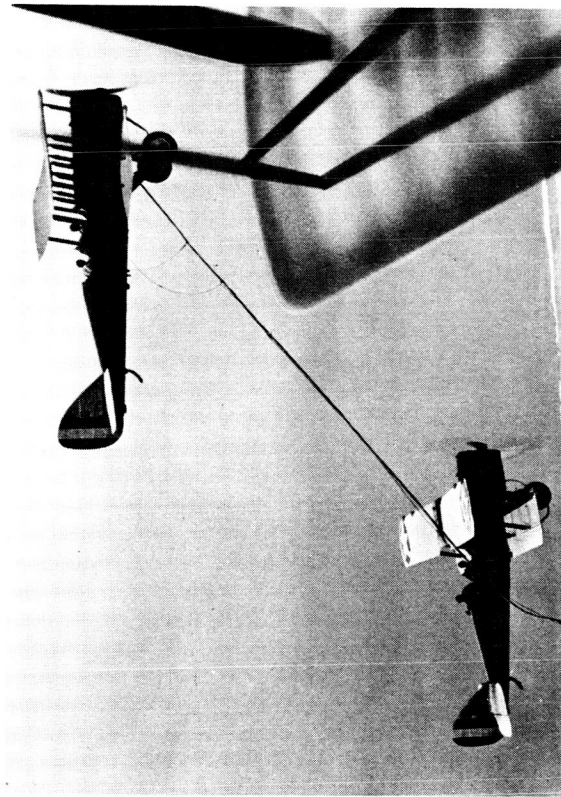




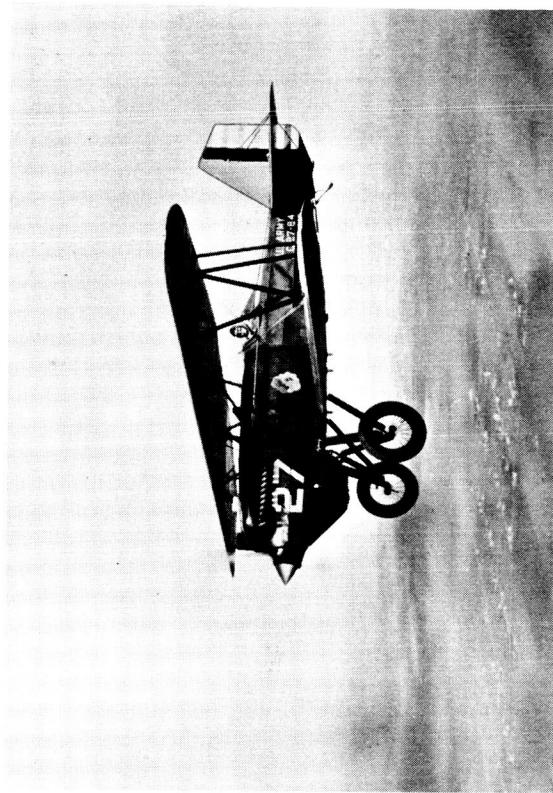
I-9. HANDLEY-PAGE BOMBERS of British design were manufactured in the United States during World War I. With a gross weight of more than 14,000 pounds, this twin-engine aircraft was truly a "heavy" of its time. Air Marshall Hugh M. Trenchard organized British-built heavies like these into an independent Strategic Bombardment Force for attacks against the German homeland.



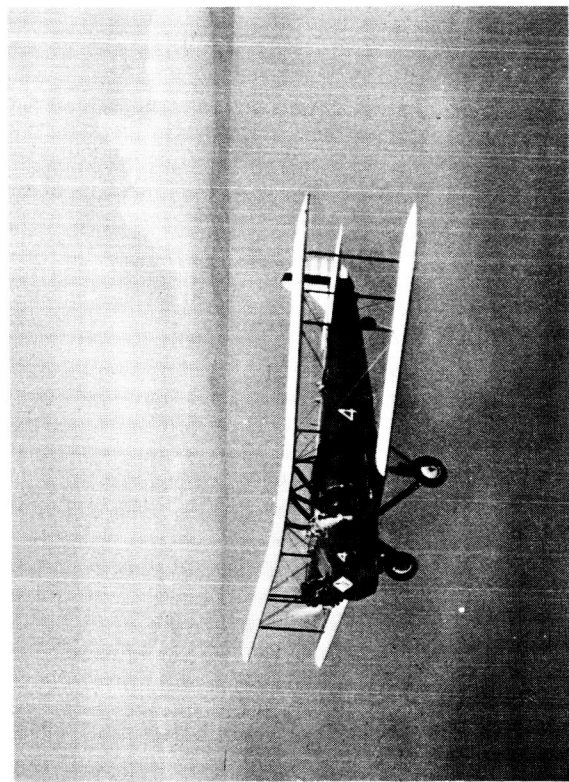
I-10. THE SALMSON 2 A.2 was a French-designed, two-place observation plane used by the Air Service of the American Expeditionary Forces in World War I. The United States procured 705 of these planes for use in 10 A. E. F. Air Service observation squadrons serving in France. Powered by a 750-hp. engine, the Salmson had a top speed of 116 m. p. h.



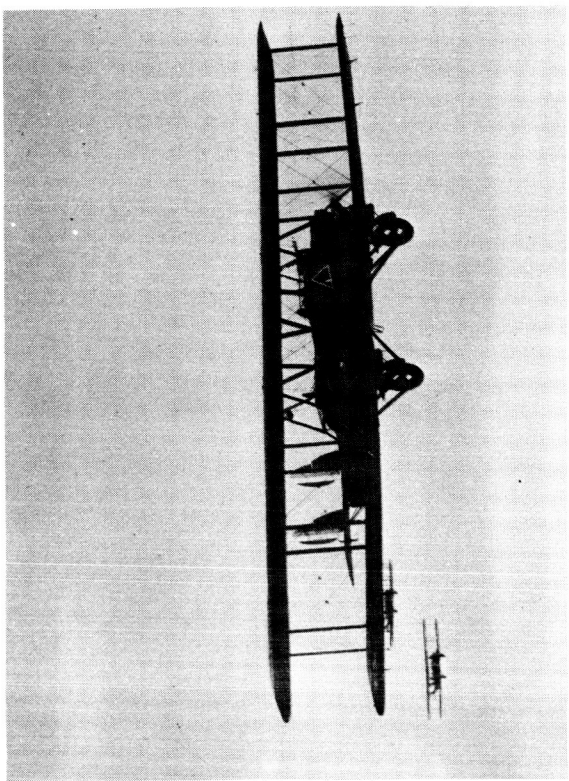
I-11. REFUELING TESTS using DeHavilland 4-Bs were conducted by military aviators in 1923. These tests set the pattern for techniques that were to be so important in the development of aviation. As crude as the equipment was, an endurance record of 37 hours and 15 minutes was established by these pioneering pilots.



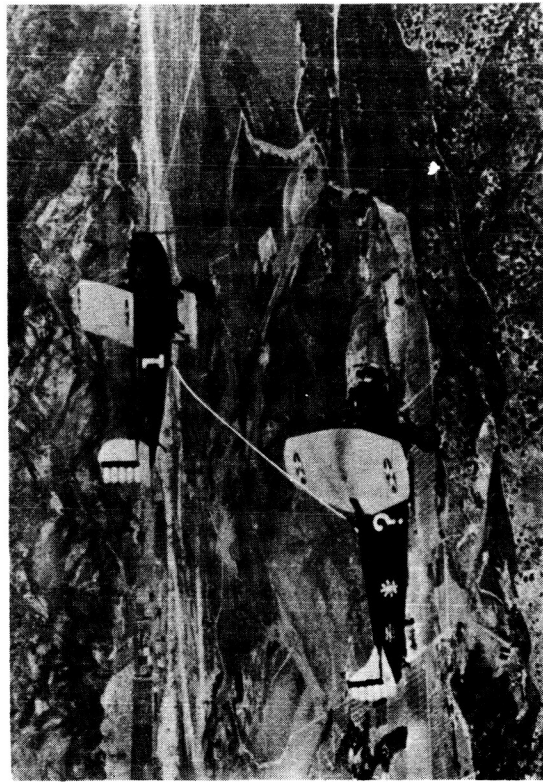
I-12. THE CURTISS HAWK P-1 flew from New York to San Francisco in 1924. The 2,670-mile flight, made in 21 hours and 48 minutes, included five stops. This Hawk biplane was refined from the P-1 through the P-6. The later versions were the first airplanes to exceed 200 m. p. h. in level flight.



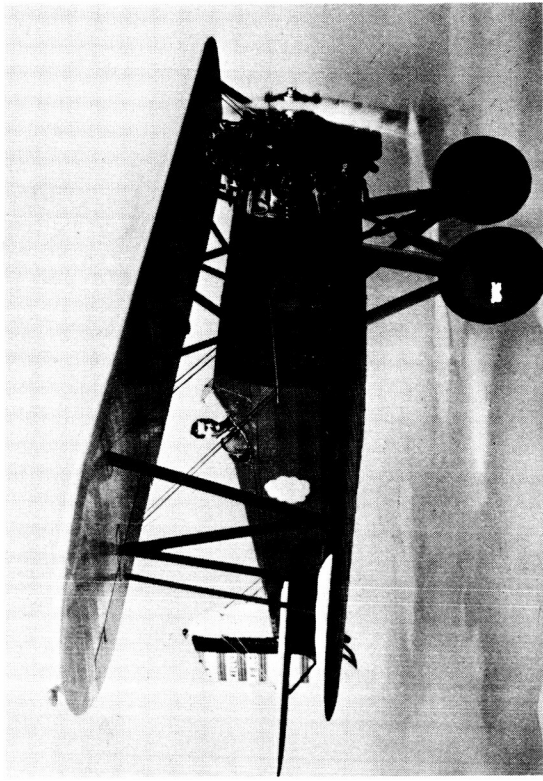
I-13. THE KEYSTONE B-3, first of the "B" category bombers. Delivered to the newly established Army Air Corps, it had a 74-foot 8-inch wing span and a gross weight of more than 12,950 pounds. The B-3 was powered by two 525-hp., air-cooled radial engines and had a crew of five.



I-14. "MOSQUITOES TO KILL ELEPHANTS" was said of Gen. Billy Mitchell's Martin MB-2 bombers when he sent them against battleships. During tests conducted in 1921 and 1923, three war-prize German warships and two obsolete U. S. battleships were sunk by these aircraft.

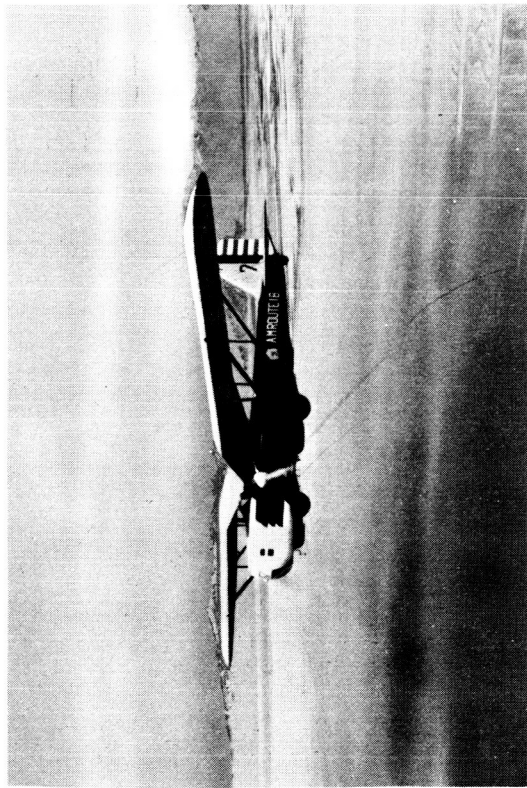


I-15. THE "QUESTION MARK," A FOKKER C-2, supplied more answers to refueling techniques when it set an endurance record of almost 151 hours, in 1929. Forty-three times during the historic flight the refueling plane hovered less than 20 feet over the appropriately named "Question Mark," passing down food, supplies, and more than 5,000 gallons of gas.

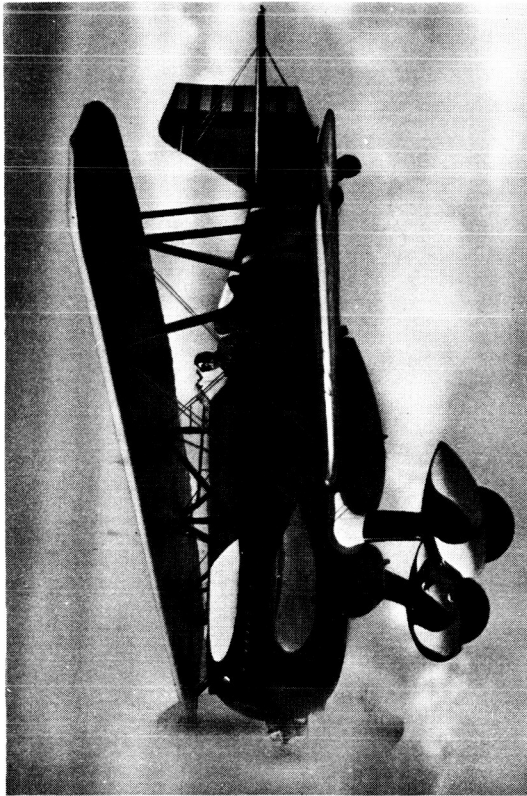


I-16. THE BOEING P-12 series pursuit aircraft was one of the finest biplane fighter aircraft ever designed. It was a highly maneuverable, sensitive plane. Grossing only 2,700 pounds, this little pursuit with its 450-hp. engine and a skilled pilot at the controls could loop on takeoff; a feat that attested to the outstanding design of this fabulous aircraft.

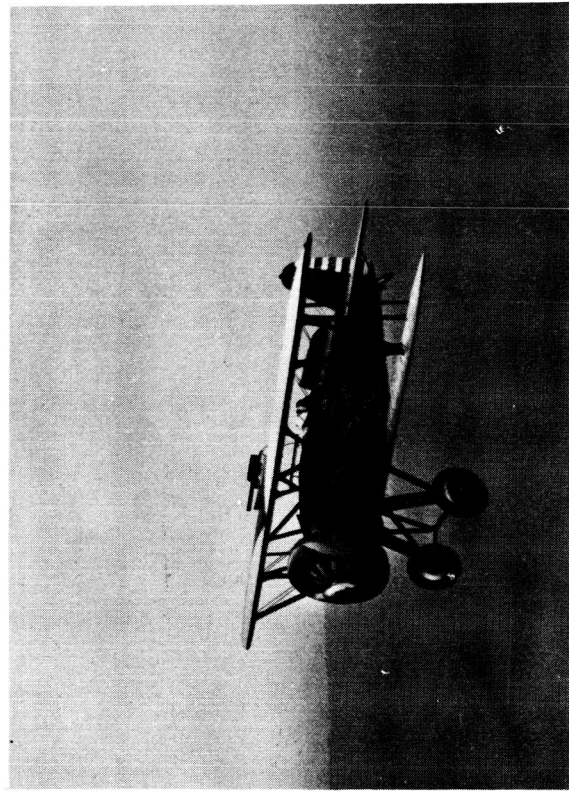




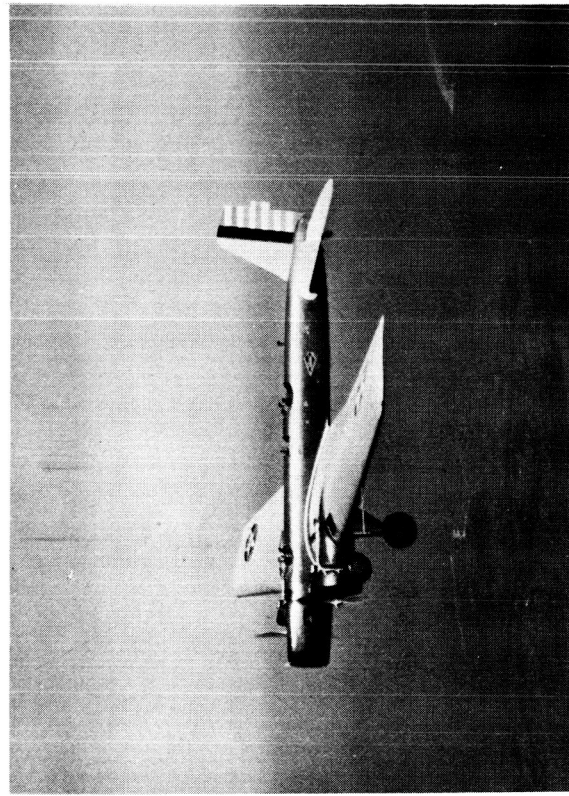
I-17. THE DOUGLAS B-7, a transitional product of new bomber theories, still had the struts that typified the age of the biplane. Designed as a fast day-bomber, it had fabric-covered wings, and all-metal fuselage, metal control surfaces, and hydraulically operated, retractable landing gear. The B-7 flew mail over the Salt Lake City-Oakland route in early 1934 when the War Department was directed to take over all domestic air mail flights.



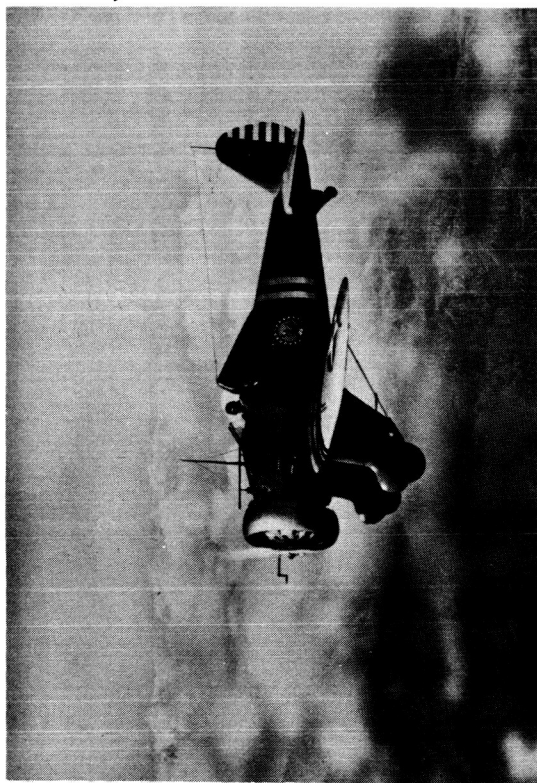
I-18. THE CURTISS P-6E was the most famous of the Hawk series of pursuits. One of the most beautiful biplane fighters ever built for the Air Corps, it was highly maneuverable and armed with two synchronized machineguns. Powered by a 600-hp. liquid-cooled Curtiss engine turning a three-bladed prop, this little fighter had a top speed of 197 m. p. h. A later model, the P-6F, was the first military aircraft to exceed 200 m. p. h. in level flight.



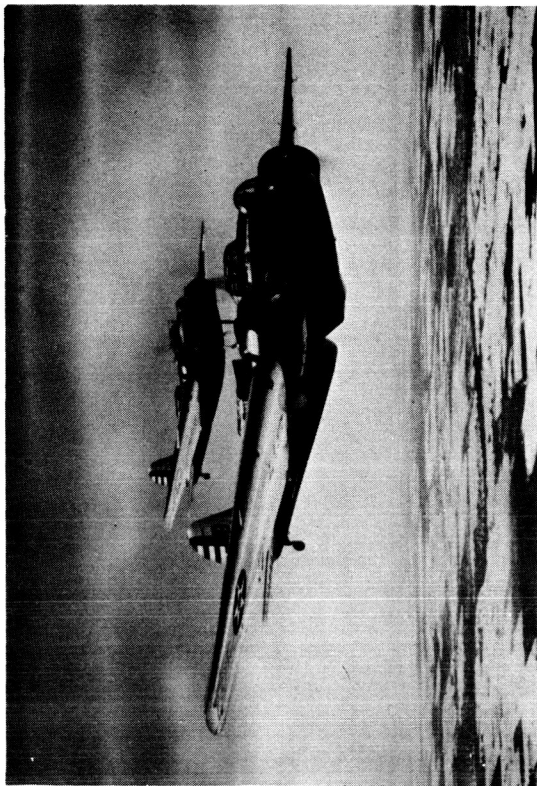
I-19. THE P-12E by Boeing was the first production-built Air Corps pursuit with an all-metal, monocoque fuselage. The P-12s had a long service life, serving with frontline squadrons from 1929 to 1936. In all, 366 of this series were produced, 110 of them being E models.



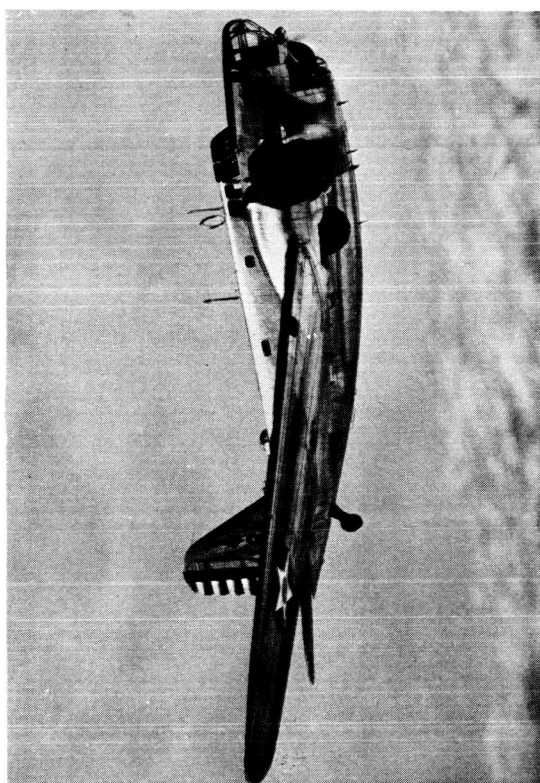
I-20. A NEW AERODYNAMIC concept was introduced when Boeing Aircraft Co. produced the B-9 low-wing, all-metal monoplane in the 1930's. Earlier bomber aircraft, generally designed for multi-purpose use, could not be as effective as one planned for a specific mission.



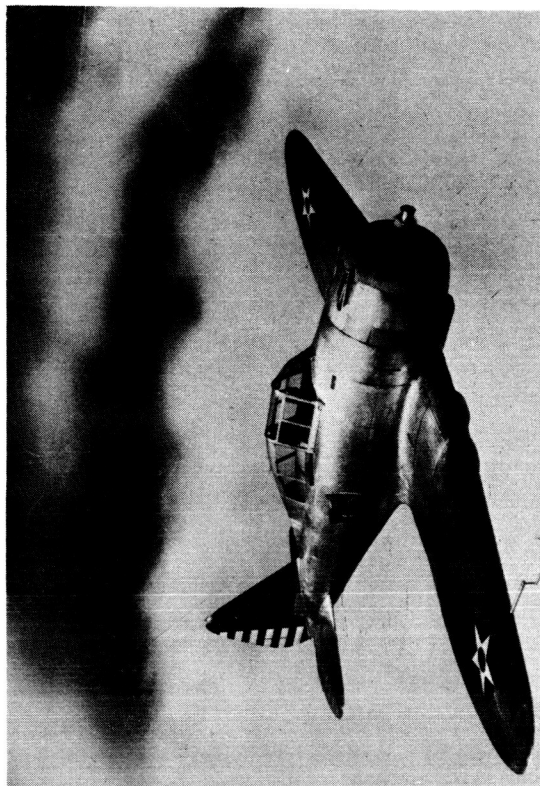
I-21. THE BOEING P-26 PEASHOOTER, designed to meet the increasing performance of the new bombers, was the first all-metal, low-wing fighter delivered in numbers. During this period, many thought the pursuit ship obsolete. Bombers were becoming so much faster that it was difficult for fighters to keep up with them.



I-22. A NEW GENERATION of bombers was realized with the production of the Martin B-10. Featuring enclosed cockpits, a power-operated turret, retractable landing gear, and newly designed engine cowlings, it had a top speed of 212 m. p. h.

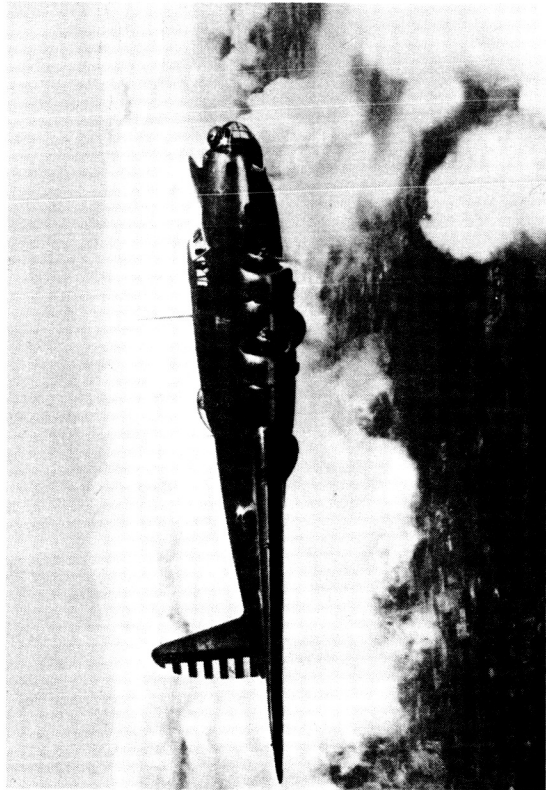


I-23. AIR CORPS BOMBER COMPETITION of 1936 resulted in Douglas Aircraft Co. getting an order for 177 B-18 Bolos. Quite similar in appearance to the famed DC-3 commercial airliner just coming off Douglas production lines, the Bolo was a very reliable, well-performing plane.

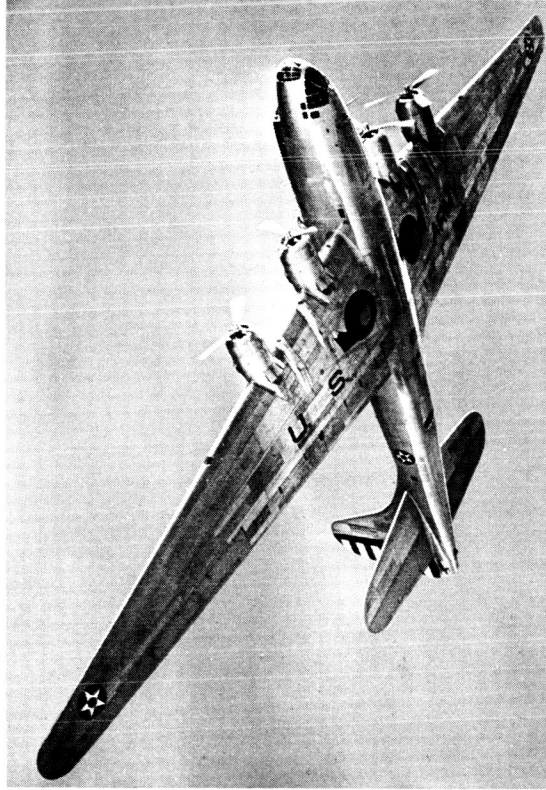


I-24. THE P-35 OF MAJ. ALEXANDER DESEVERSKY's aircraft company (1936), a forerunner of future fighters, proved to be a wonderful airplane to fly. Almost 50 m. p. h. faster than the P-26, its armament still did not make it the fighting machine pilots needed to keep up with bomber development.

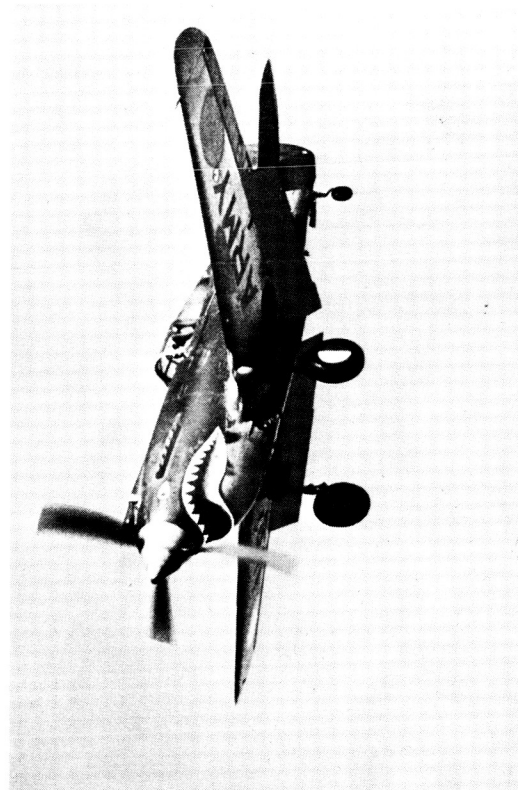




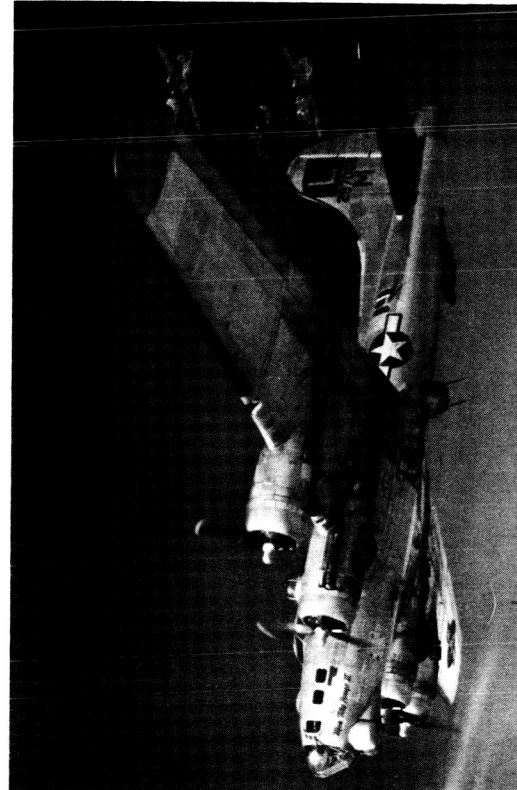
I-25. IN AUGUST 1934, Boeing began construction of the XB-17. First flown in July 1935, it led the way to one of the world's most famous series of bomber airplanes. Flying characteristics of this plane were outstanding for the time, establishing performance records that far outclassed most airplanes of the era. It had a top speed of 256 m. p. h., service ceiling of 30,600 feet, and a maximum range of 3,320 miles.



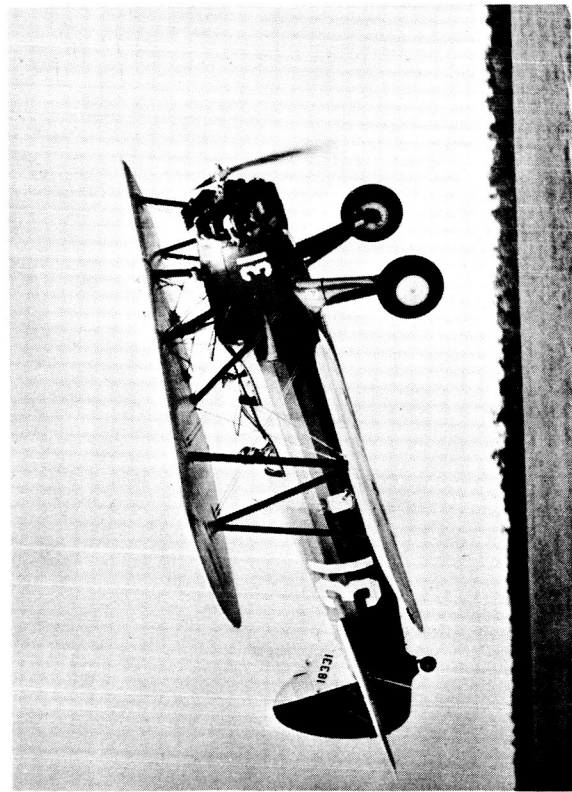
I-26. THE DOUGLAS XB-19, conceived in 1935, first flew in 1941. The culmination of six and a half years of engineering, this giant aircraft dwarfed all others of the time. It had a wing span of 212 feet, a 132-foot 4-inch fuselage, 8-foot main tires, and a rudder 42 feet high. It had a range of 7,710 miles with a fuel load of 10,400 gallons.



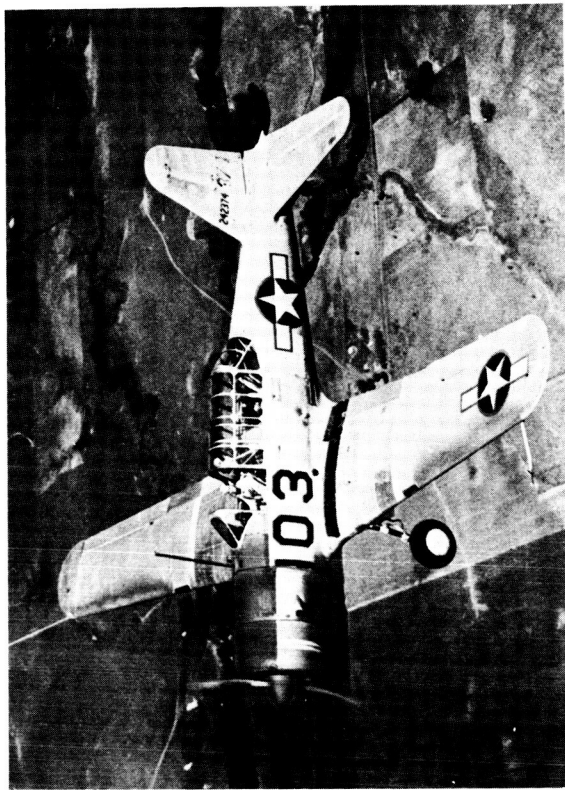
I-27. HAWK-TOMAHAWK-KITTYHAWK-WARHAWK were the official names given to the Curtiss P-40. Praised, abused, called excellent and inferior, this much-discussed World War II fighter saw action on every fighting front in the world. Always less maneuverable and slower than first-line German and Japanese adversaries, it proved far more rugged.



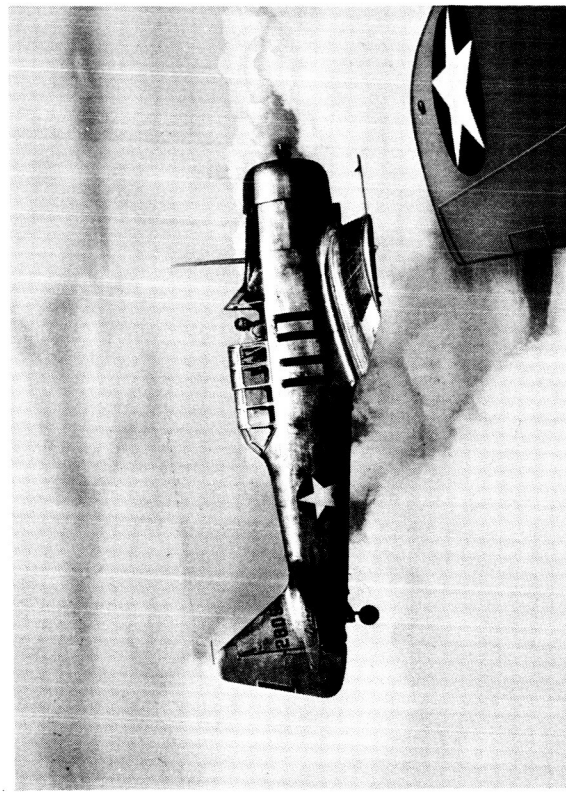
I-28. THE WORLD WAR II FLYING FORTRESS, scourge of the skies over embattled Europe, no longer had the thin, graceful lines of its 1936 sister. Redesigned to take the war to the enemy, the slim bomber had given way to a broad dorsal fin that enclosed twin stinger 50-cal. machineguns in the tail. Top and belly turrets bulged from the fuselage, showing their ugly gun snouts. Airmen gunners stood at open side hatches with their 50s bearing on anything that came their way.



I-29. THE STEARMAN PT-17 KAYDET was used for primary flight training prior to and during World War II by both the Air Force and the Navy. Equipped with a 220-hp. engine, the two-place biplane had a top speed of 135 m. p. h.



I-30. THE VULTEE "VIBRATOR" (BT-13) was familiar to thousands of fledgling pilots going through basic flying training in the 1940's. It was in this second phase of training that pilots fresh from civilian contract schools got their first taste of military life and air tactics.

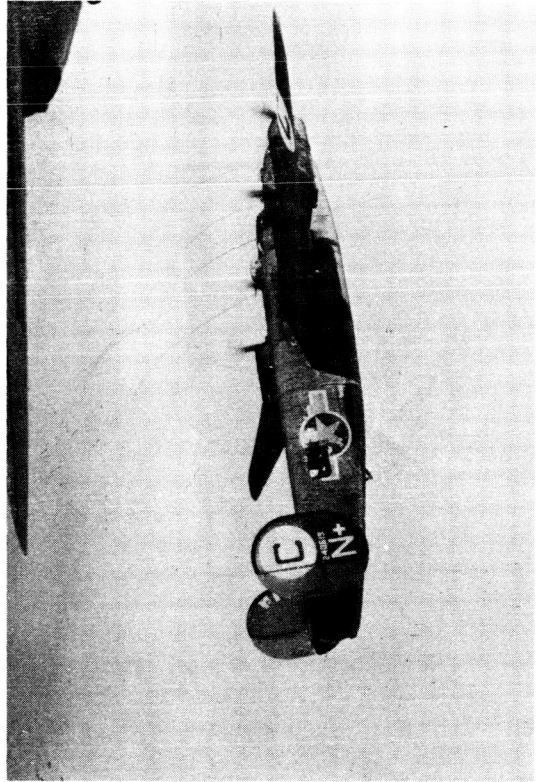


I-31. FLOWN BY more military pilots, worldwide, than any other aircraft, the North American AT-6 Texan had an unusually long service life. Produced as an advanced trainer in 1938, it was used in U. S. Air Force pilot schools until September 1956.

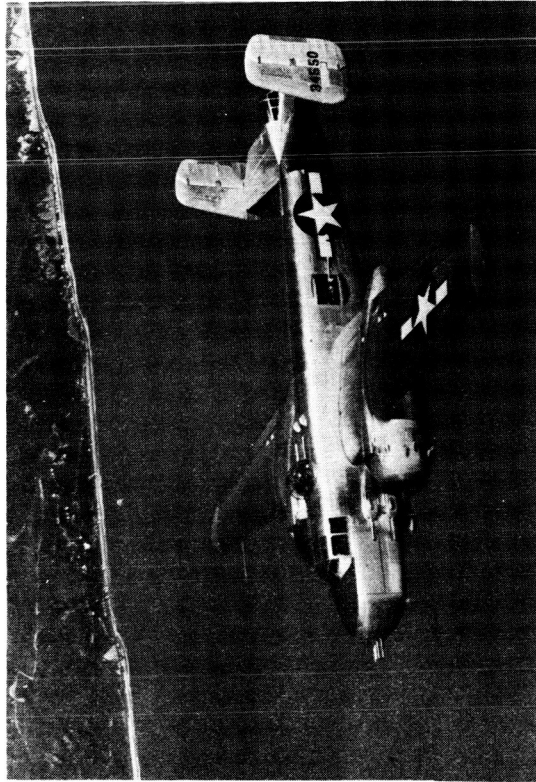


I-32. THE DOUGLAS A-20 was developed from a bomber designed for the French in 1937 and first flown in 1938. Designated the Havoc by the Americans, early production models were delivered to the British, who renamed them the Boston.

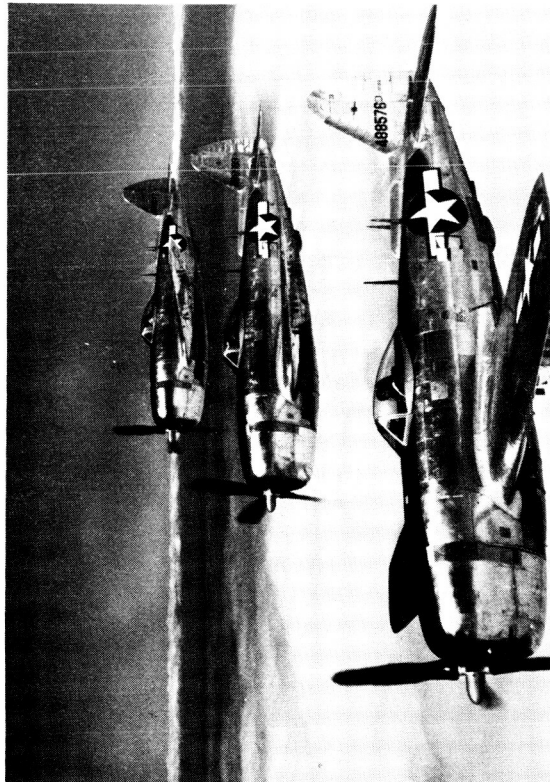




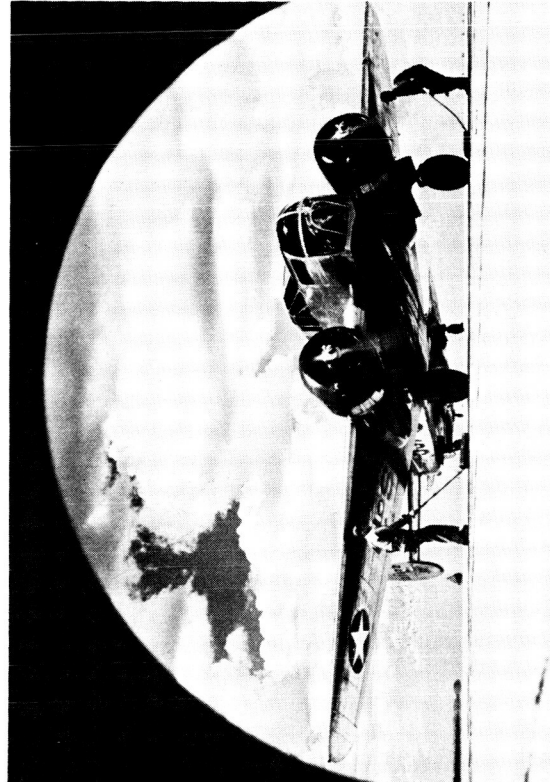
I-33. THE CONVAIR B-24 LIBERATOR is probably best remembered for its employment in early raids on Nazi oil refineries at Ploesti, Rumania. Losses during the Aug. 1, 1943, raid on Ploesti were extremely high. Of the 163 Liberators that reached the target, 54 were lost, and 144 airmen killed or missing.



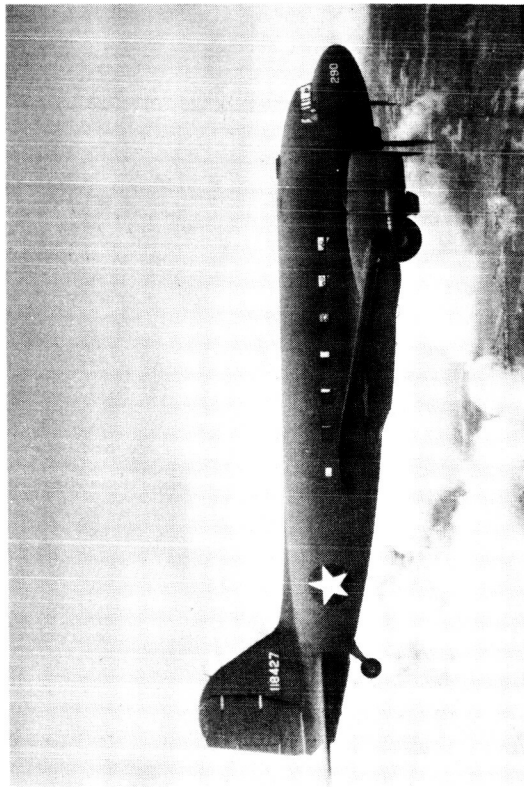
I-34. THE NORTH AMERICAN B-25 MITCHELL bomber, named after Gen. Billy Mitchell, saw combat in most World War II theaters. The most famous exploit of this versatile plane was unquestionably the Air Corps-planned, carrier-based attack that Lt. Col. Jimmy Doolittle led against the Japanese mainland early in the war.



I-35. "JUGGERNAUT," or affectionately "Jug," was the name given to the rugged Republic P-47 Thunderbolt by its pilots. Twice as heavy as any single-engine fighter ever built, the 47 was the culmination of years of work by Maj. Alexander DeSeversky.



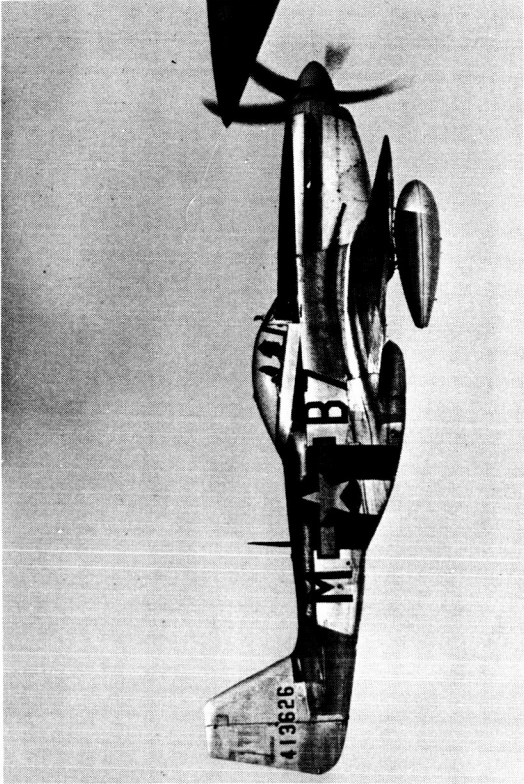
I-36. IN CONTINUOUS production since 1937, the twin-tailed, model 18 Beech light commercial transport was adapted to navigator and bombardier training during World War II. As the Plexiglass-nosed Beech AT-11, it was a familiar classroom to the 45,000 World War II bombardier cadet graduates.



I-37. DC-3, C-47, DAKOTA, and SKYTRAIN were the official names of this world-famous Douglas-built cargo and passenger plane. To her crews, however, this lovable old bird was called the "Gooney." Large airline demands for this model and resultant production improvements led to the DC-3 in June 1936. This is the plane that became the workhorse of the Services during World War II.



I-39. THE C-46 COMMANDO, built by the Curtiss-Wright Corp., first saw action late in World War II. With a capacity of 15,000 pounds, it was the largest twin-engine plane at the time. The Commando served in all theaters as a troop and cargo carrier, flying ambulance, and tow plane for gliders.

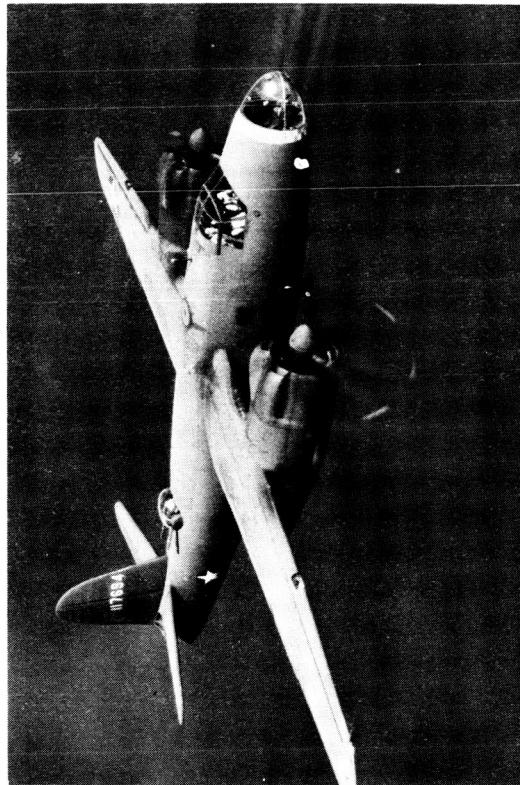


I-38. THE P-51 MUSTANG was originally designed for the Royal Air Force in 1940. With a deadline of 120 days for delivery, North American Aviation achieved the impossible, producing the first model in 117 days. Called the best all-around American-built fighter of World War II, it was faster, more maneuverable, and most important, had a greater cruising range than any other fighter in the USAAF.

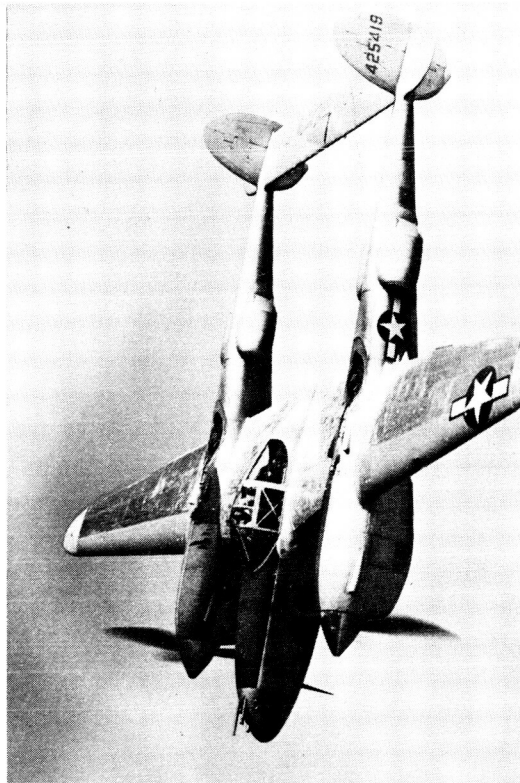


I-40. THE CONSOLIDATED B-24 PEACEMAKER was the biggest bomber, in size, to enter the Air Force inventory. Development began in 1941. It was not flown, however, until the fall of 1947. The Peacemaker lived up to its name in helping to deter general war for more than 10 years. Four turbo jets were paired in pods under each wing, giving the 230-foot long bomber a speed of 435 m. p. h., ceiling of 45,000 feet and a bomb load of 84,000 pounds.

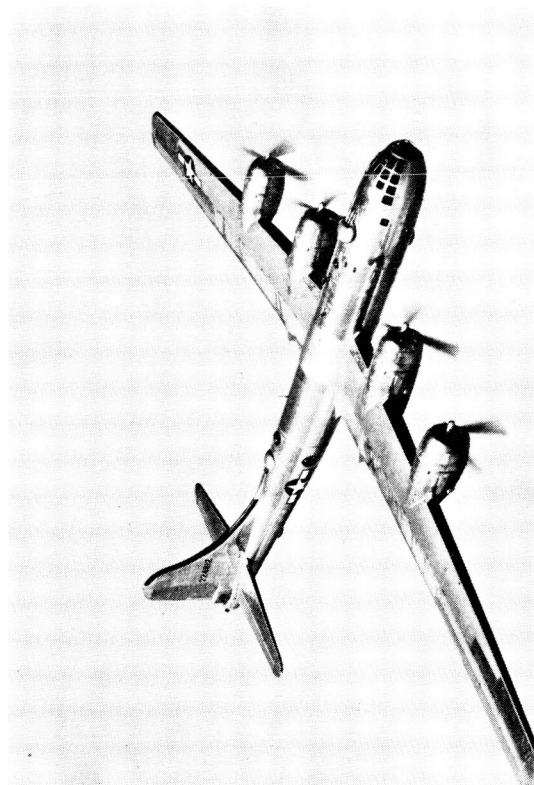




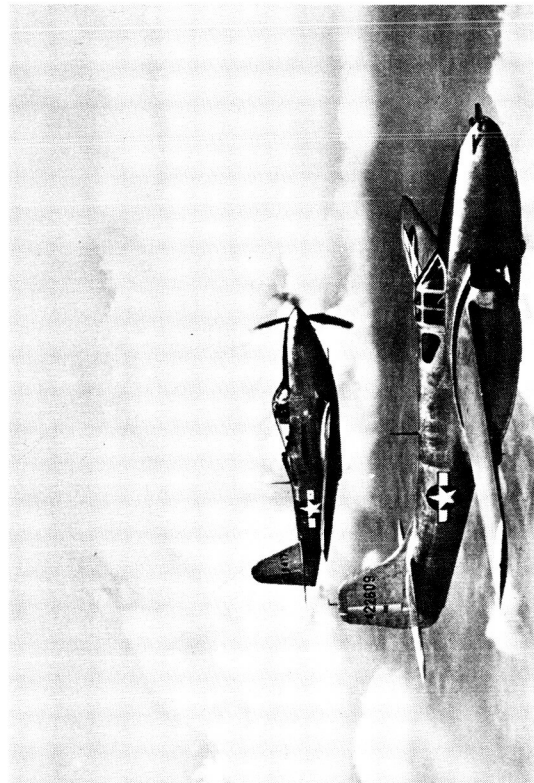
I-41. BUILT BY MARTIN, THE B-26 MARAUDER amassed a creditable combat record in Africa, Europe, and the Pacific, during World War II. With its usually high wing loading and a landing speed of 135 m. p. h., the Marauder was one of the most controversial airplanes of its time.



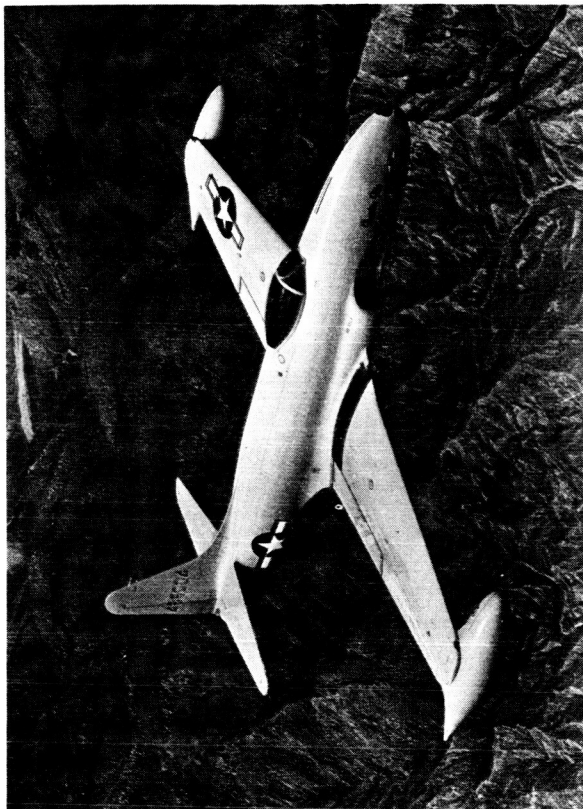
I-42. OPERATIONAL IN 1942, the Lockheed P-38 Lightning was designed in 1937 and first flew in 1939. Known as the "Fork Tailed Devil" by the Germans and Japanese, the Lightning piled up an impressive record in Europe and the Pacific. With hydraulic aileron boost and counterrotating props, it was a wonderful airplane to fly. A rapid roll, the ability to dive at extremely high speeds (up to 780 m. p. h.), and concentrated firepower made it a formidable adversary.



I-43. THE B-29 SUPERFORTRESS built by Boeing has been called the weapon that won the war in the Pacific. Designed to carry large bomb loads long distances, it made possible the strategic bombardment that brought Japan near to collapse. It was a very sophisticated airplane with a pressurized cabin, highly advanced remote-control gun-firing system, and tremendous bomb capacity.

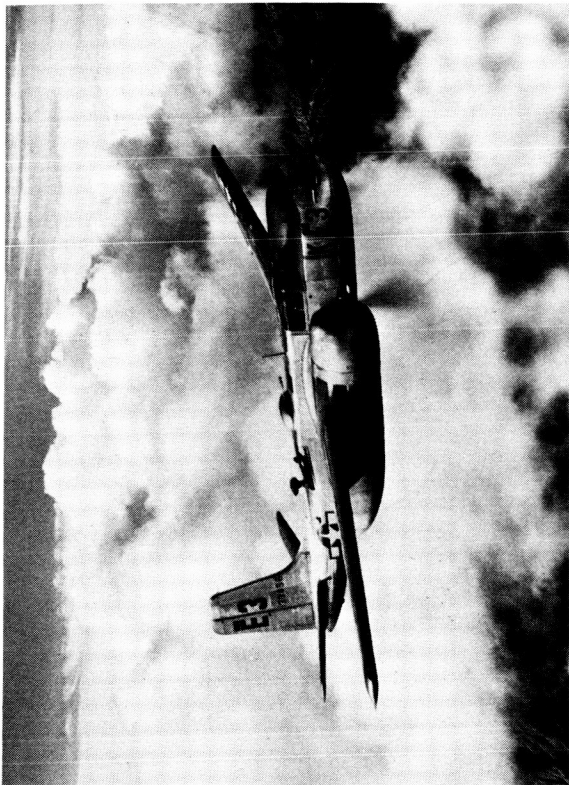


I-44. THE FIRST JET aircraft produced for the USAAF and flown in October 1942 was the Bell XP-49A Airacomet. Powered by twin 2,000-pound-thrust jets, this airplane was not as fast as the operational fighters of the time.

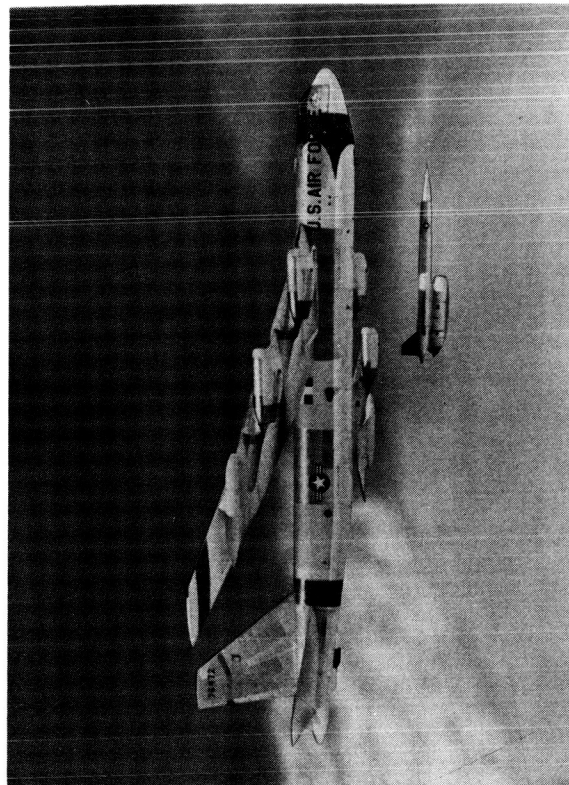


I-45. DEVELOPMENT of the jet-propelled Lockheed P-80 Shooting Star marked the dawn of the jet age. The Shooting Star, designed as an answer to the enemy jets appearing in the skies over Europe, was built in the record time of 143 days. The prototype of this jet flew on Jan. 8, 1944.

Figure 2. - USAF current aircraft (1967). (Shown in photographs II-1 to II-25.)



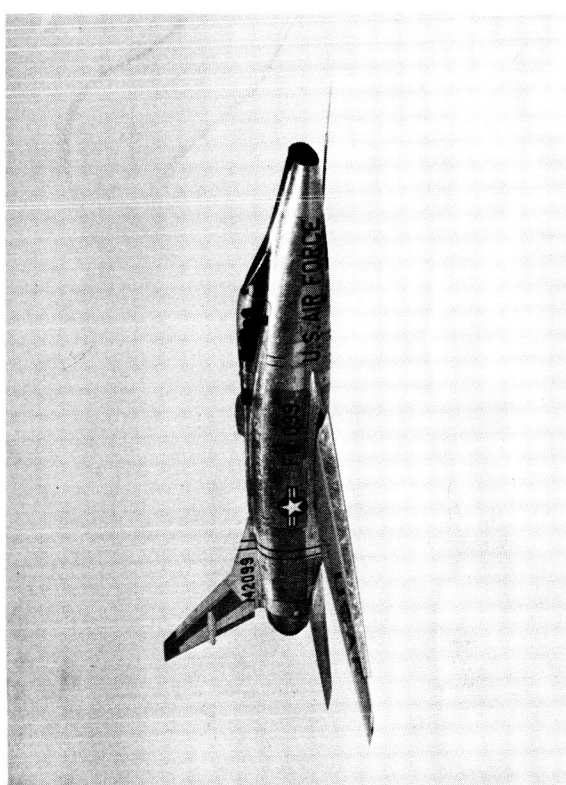
II-1. The B-26 INVADER is a tactical light bomber well suited for counter-querrilla air action. The earliest models of the B-26 (then the A-26) saw service during the Battle of the Bulge in World War II. Extremely versatile, it has a speed of more than 350 miles per hour.



II-2. The USAF's B-52 STRATOFORTRESS has been the Strategic Air Command's primary heavy bomber. It can carry two HOUND DOG air-to-surface guided missiles. In 1957, three B-52's, using in-flight refueling, flew around the world; 24,325 miles in 45 hours.



II-3. The fastest bomber in the Strategic Air Command, the B-58 HUSTLER has made the longest supersonic flight in history. In October 1963, the B-58 flew nonstop from Tokyo to London in 8 hours and 35 minutes, averaging 938 miles per hour. It carries its nuclear punch in a pod slung underneath.

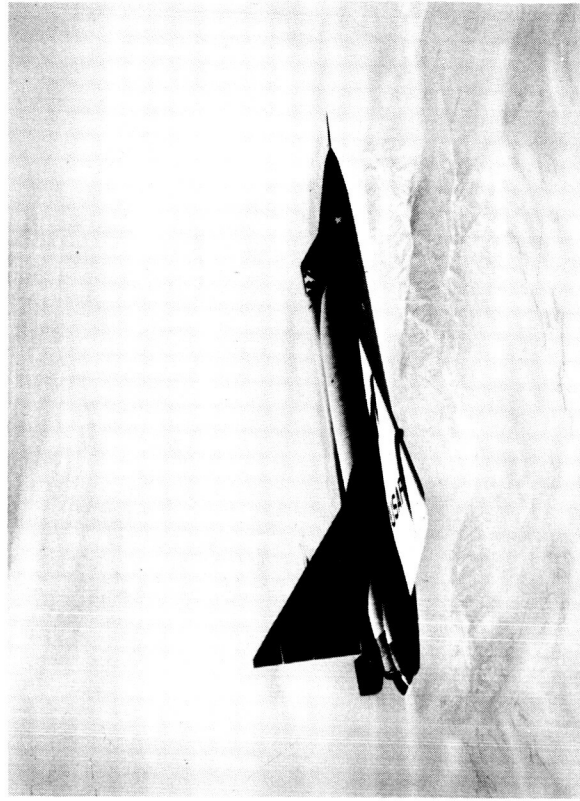


II-4. The first USAF aircraft to fly supersonic in level flight, the F-100 has been the workhorse of tactical air units. The first SUPERSABRE was delivered in late 1954.





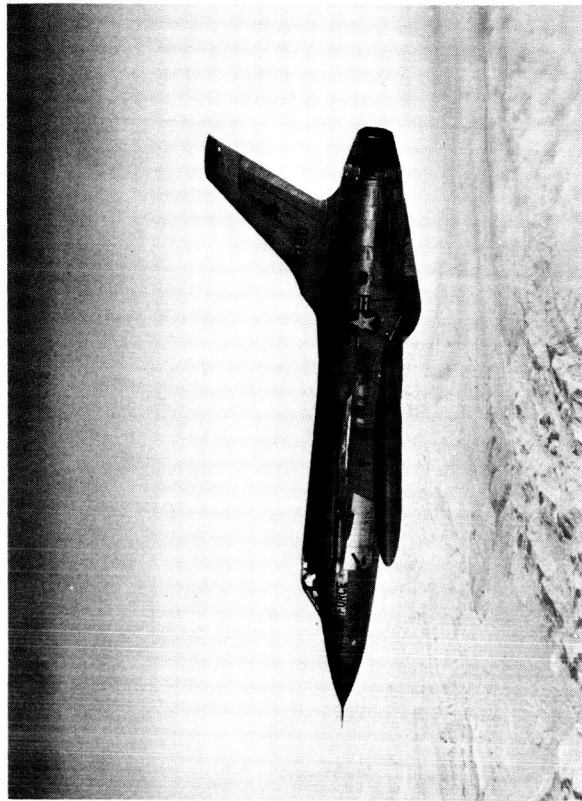
II-5. The RF-101 VOODOO was the USAF's first supersonic photo-reconnaissance aircraft. From 45,000 feet, the VOODOO can photograph an area 217 miles long and 8 miles wide, plus an area mosaic of 20,000 square miles.



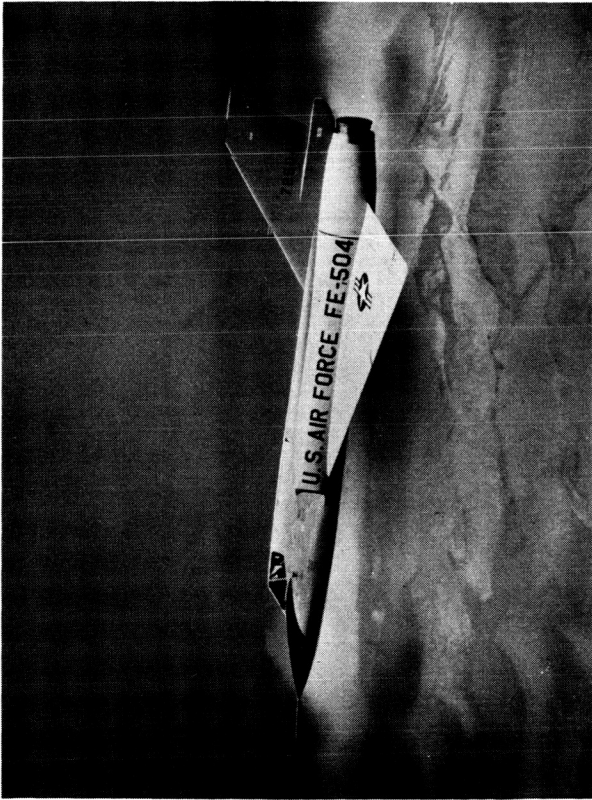
II-6. The USAF's F-102 DELTA DAGGER was the world's first supersonic all-weather jet interceptor. Flown first in 1953, it became operational in 1956. It uses electronic "eyes" to locate hostile aircraft by day or night, in good or bad weather.



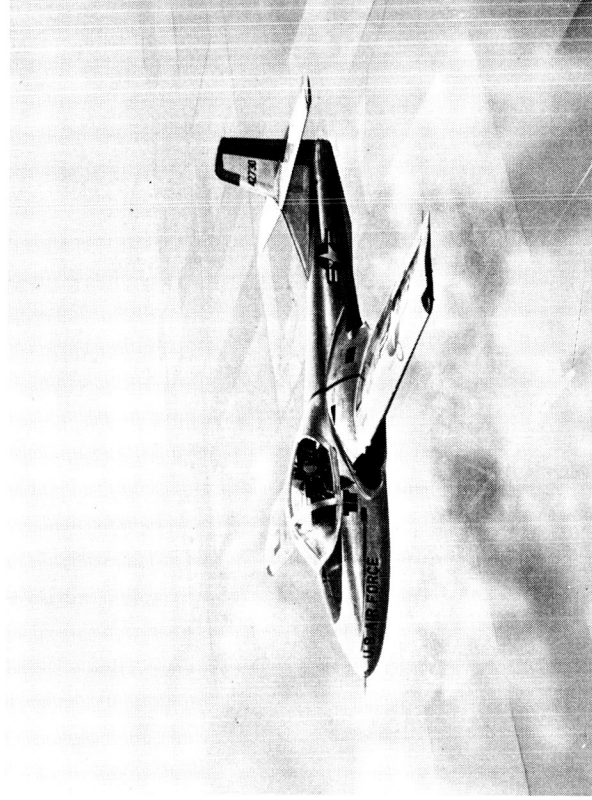
II-7. The F-104 STARFIGHTER was designed as a supersonic air superiority fighter. It serves either as a tactical fighter or as a day-night interceptor.



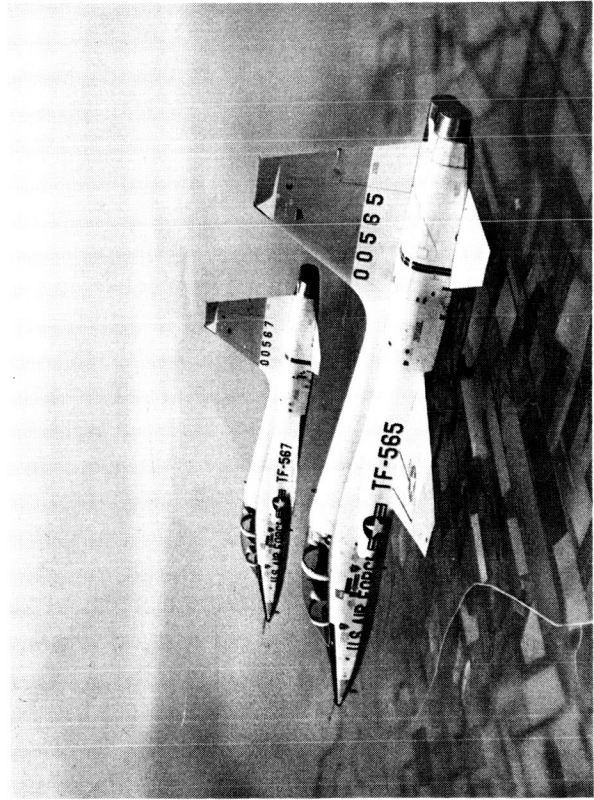
II-8. The F-105 THUNDERCHIEF is a 1400 mile-per-hour aircraft which can deliver 12,000 pounds of bombs. It also has a nuclear capability.



II-9. The F-106 DELTA DART's afterburning jet engine can push this all-weather interceptor to speeds of more than 1400 miles per hour and to altitudes above 50,000 feet.



II-10. The T-37 is a 350-mile-per-hour jet trainer.



II-11. The T-38 TALON is a basic two-place supersonic jet trainer capable of 850 miles per hour with a range beyond 1150 miles.

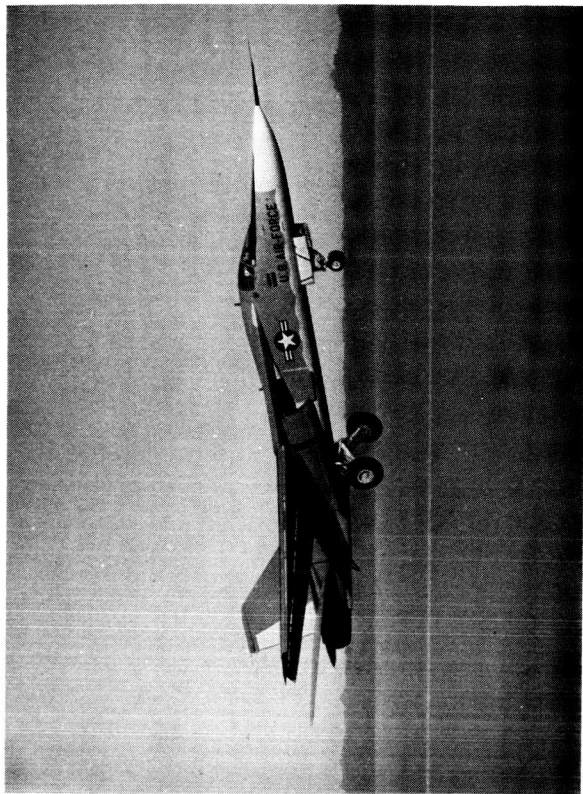


II-12. The F-4C is capable of 1600 miles per hour. It has an all-weather bombing system for use in placing either conventional or nuclear bombs on target.

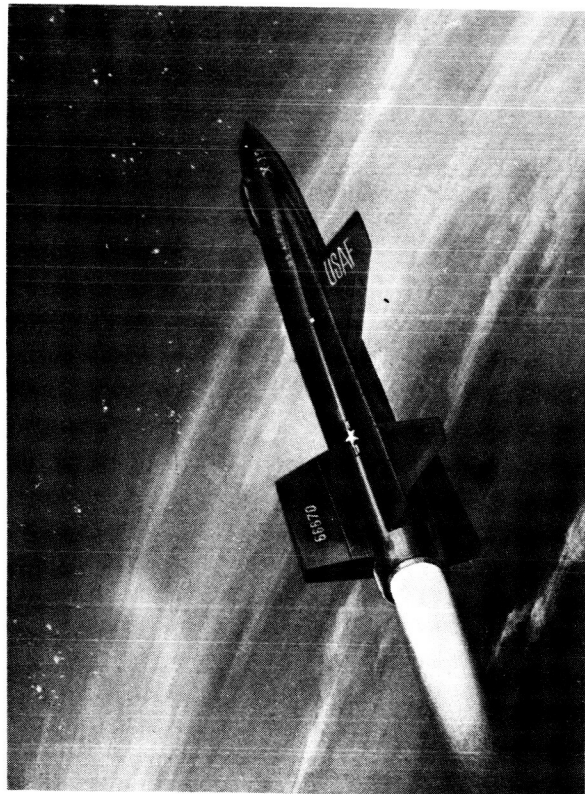




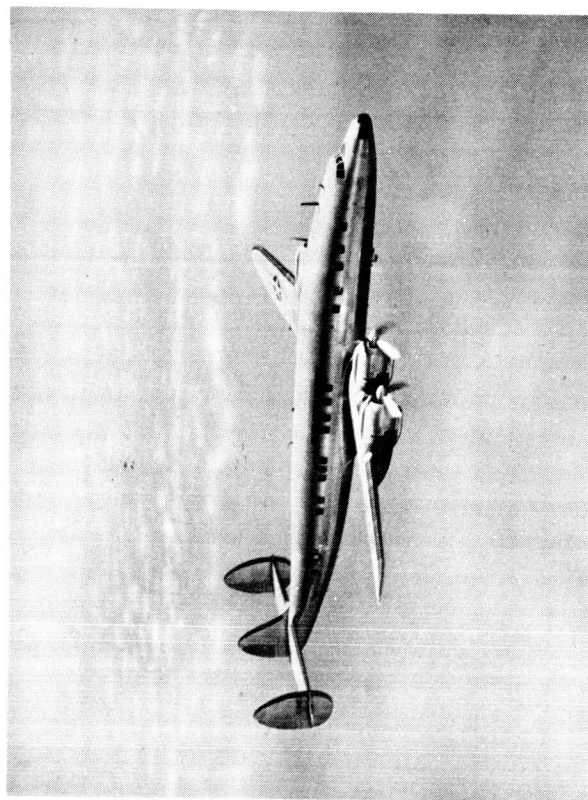
II-13. The YF-12A has been tested in sustained flight at more than 2000 miles per hour at altitudes above 70,000 feet.



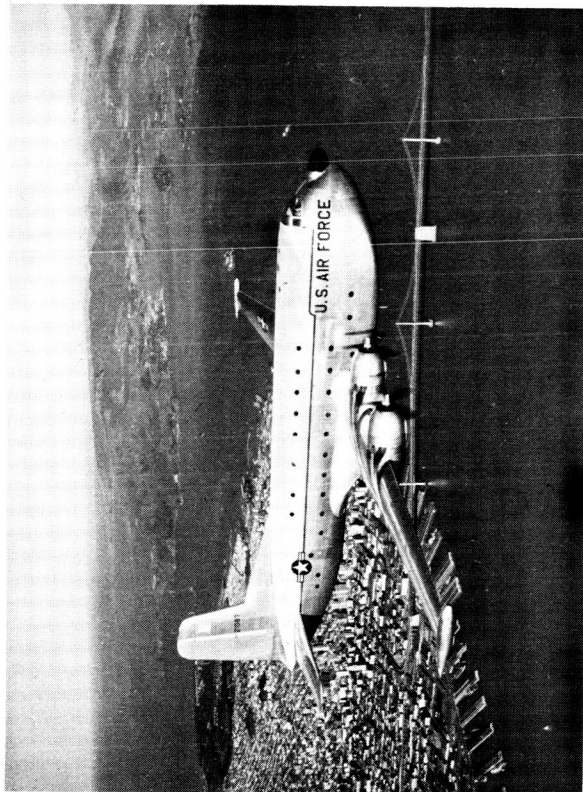
II-14. The F-111A is a fighter with wings that can be extended or swept back sharply while in flight. A multipurpose aircraft, it can be used for counterair, interdiction, close air support of ground forces, and reconnaissance.



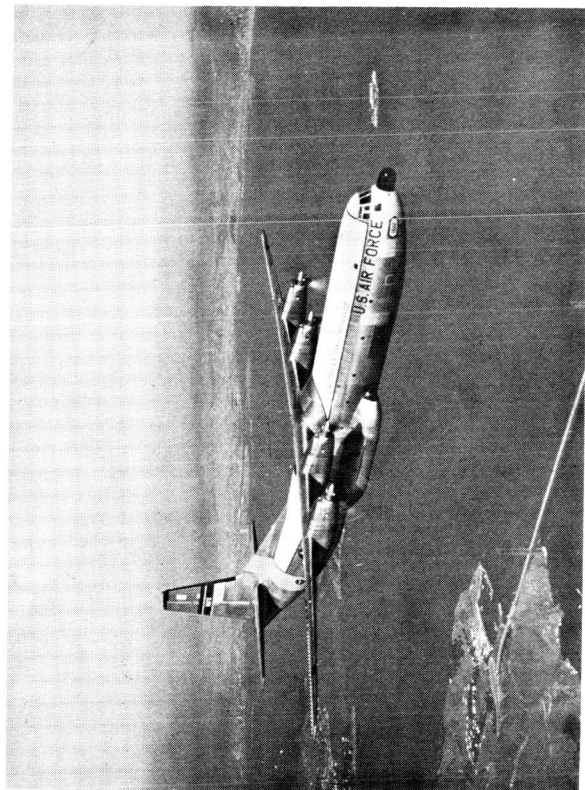
II-15. More spacecraft than aircraft, the X-15 is the product of an experimental program jointly begun by the USAF, NASA, and the Navy, to study aerodynamic, structural and physical problems encountered during hypersonic flight and re-entry.



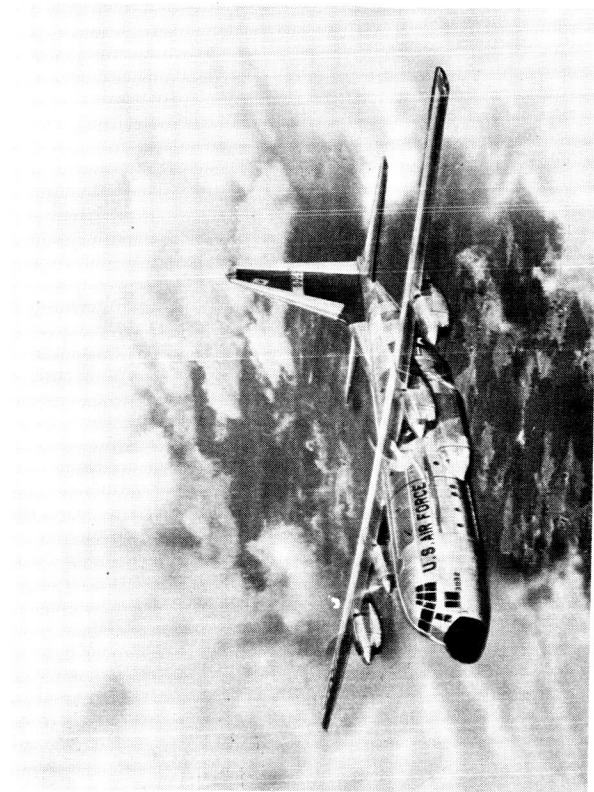
II-16. The C-121 SUPER CONSTELLATION is a four-engine transport with a cruising speed of about 300 miles per hour. It can fly more than 3500 miles nonstop.



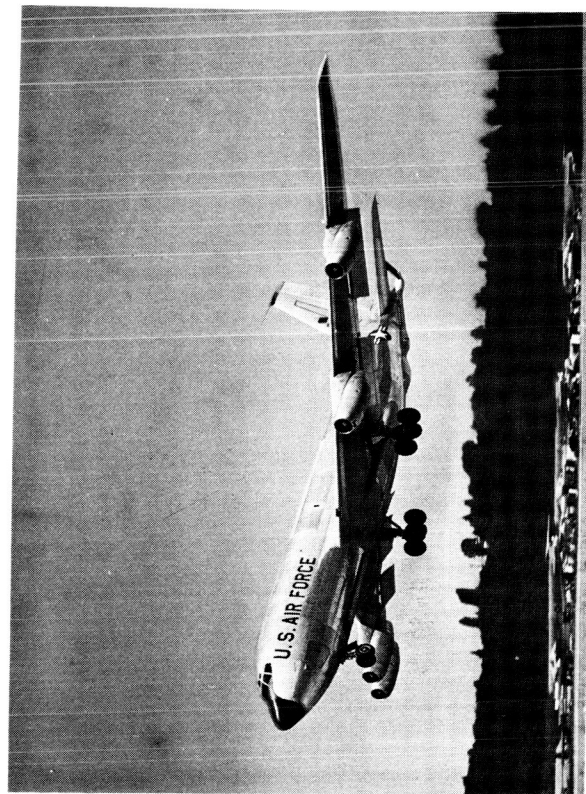
II-17. The C-124 GLOBEMASTER can carry 50,000 pounds of cargo more than 2300 miles.



II-19. The C-133 CARGOMASTER, largest turboprop transport in the USAF inventory, made its first flight in 1956. It can airlift our operational intercontinental ballistic missiles at speeds up to 300 miles per hour.

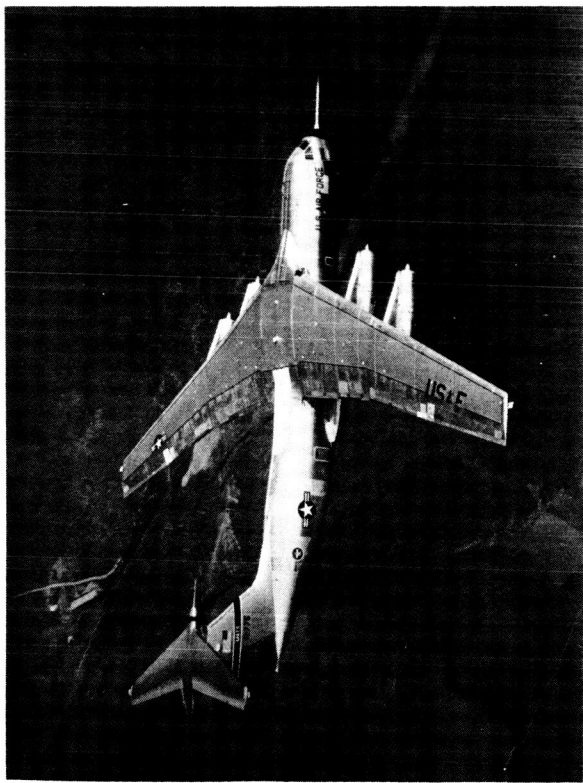


II-18. The USAF's C-130 HERCULES has made the difficult military job of aerial resupply routine. It can transport 92 combat troops with full battle gear, 64 fully-equipped paratroopers, or 74 litter patients and two medical attendants across the Atlantic nonstop.

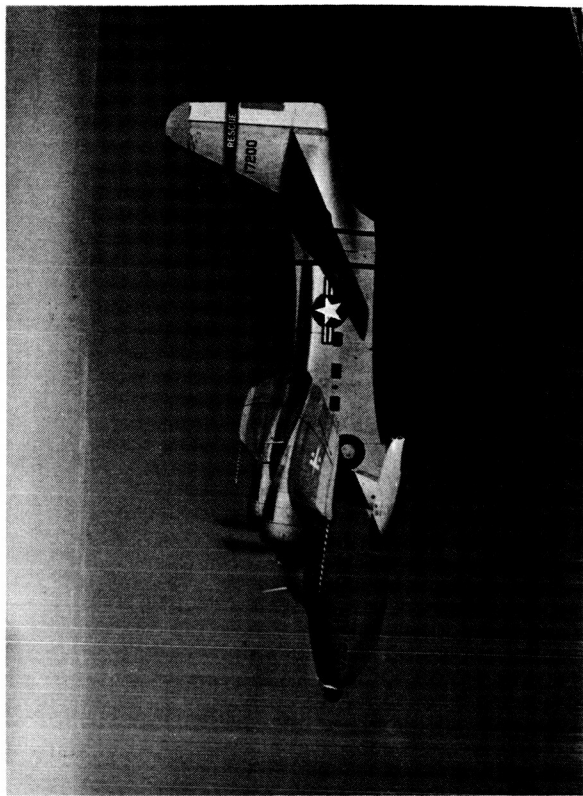


II-20. The jet-powered KC-135 STRATOTANKER first entered the USAF inventory in 1957. It functions as a "flying filling station" for jet bombers and fighters.





II-21. The C-141 STARLIFTER has a 6547 cubic-foot cargo compartment with an automated cargo handling system.



II-22. The HU-16 ALBATROSS is a twin-engine amphibian used by the Air Rescue Service. It first flew in 1947.



II-23. The HH-19 CHICKASAW is the original "whirlybird." It can fly at 70 miles per hour speeds over distances exceeding 300 miles.



II-24. The CH-21 WORKHORSE can carry 20 fully equipped troops. It also serves as a flying ambulance able to evacuate 12 litter patients and a medical attendant from locations inaccessible to conventional aircraft.

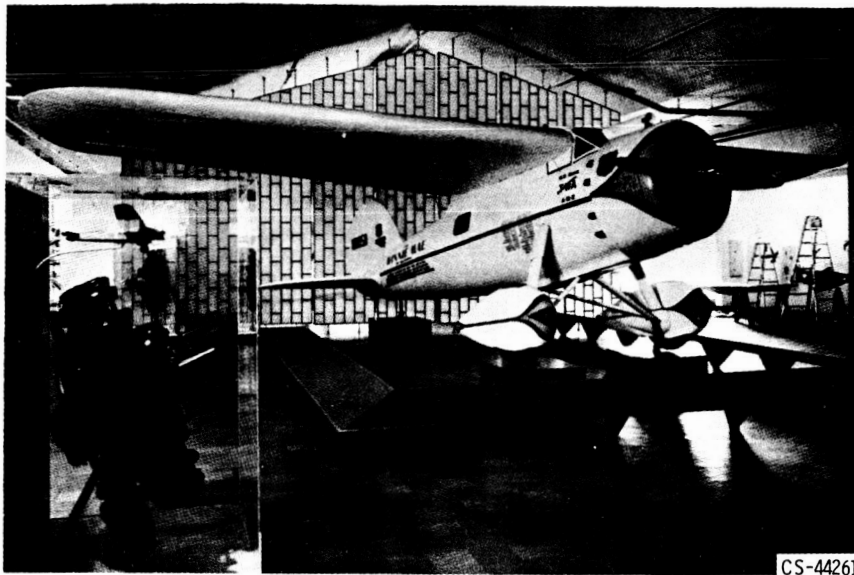


Figure 7. - The Lockheed Vega "Winnie Mae" flown solo by Wiley Post in 1933 on a record setting around-the-world trip (shown in Smithsonian Inst.).

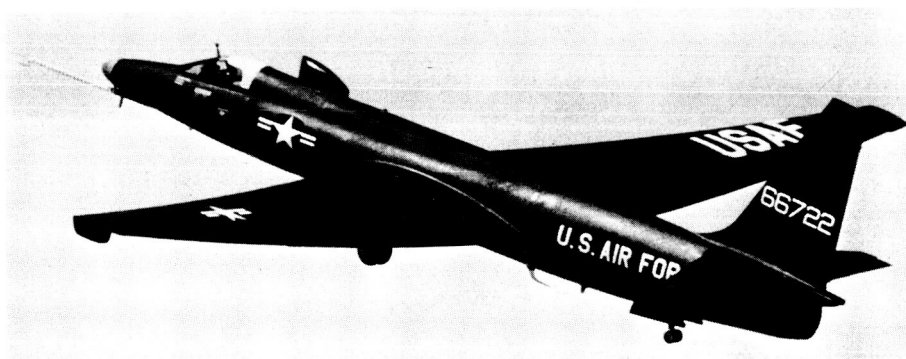


Figure 8. - Granville "Gee Bee" racer flown by Jimmy Doolittle in Thompson Trophy race for a new record in 1932. (Courtesy Model Air News.)



CS-44258  
C-67-3417

Figure 9. - Convair B-36 long-range strategic bomber in contrast to Wright Flyer.



C-67-3414

Figure 10. - Lockheed U-2 high-altitude jet aircraft for weather and radiation research and photoreconnaissance missions. (Courtesy Smithsonian Institution.)

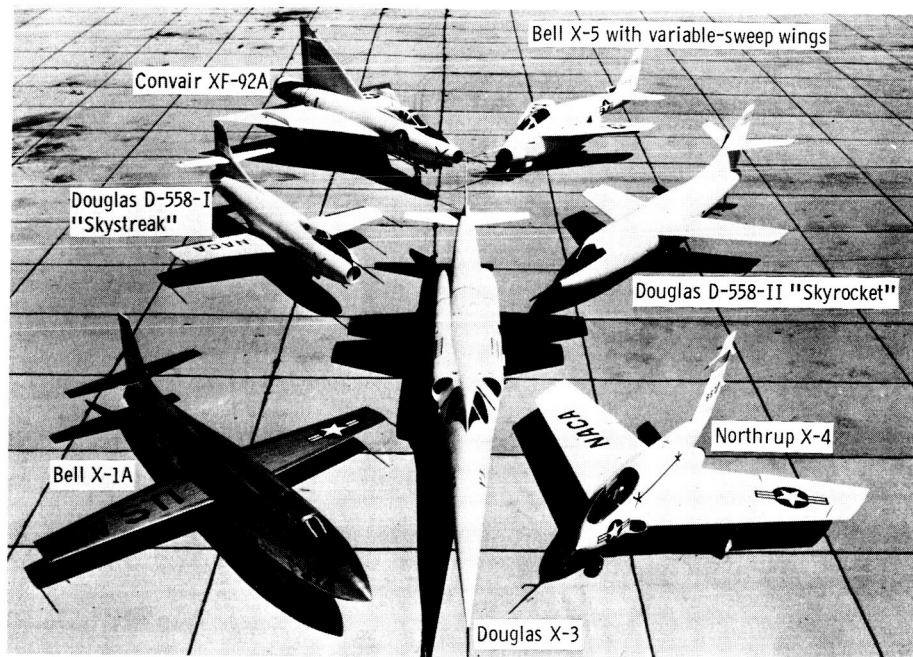
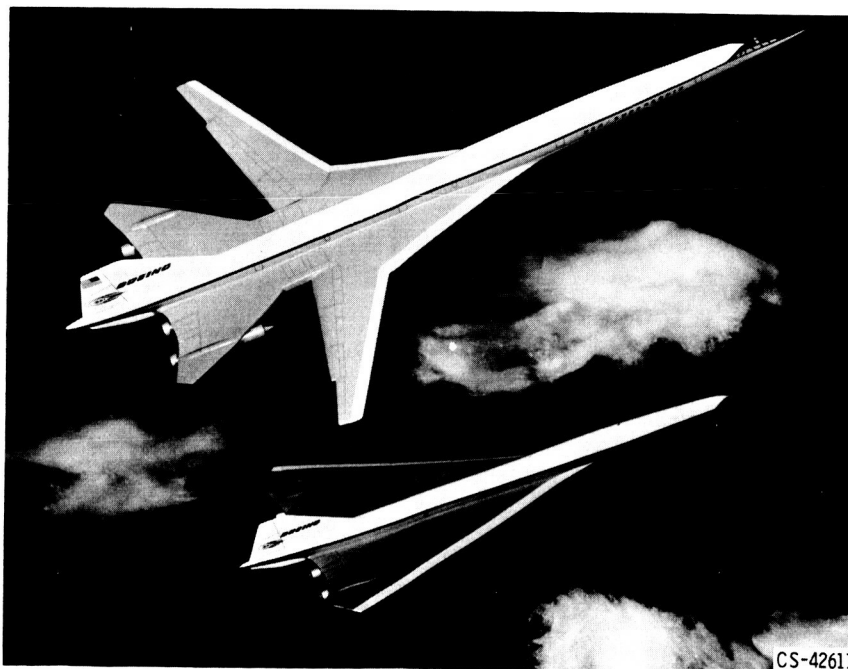


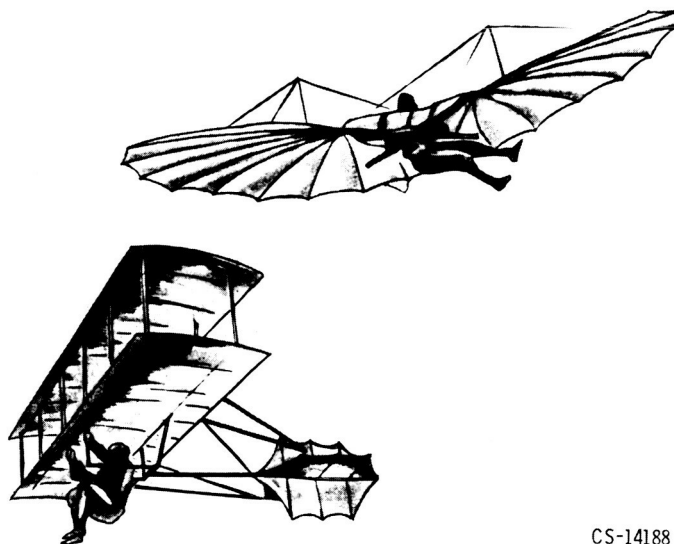
Figure 11. - Research airplanes (1956). (Courtesy Smithsonian Institution.)

C-67-3415



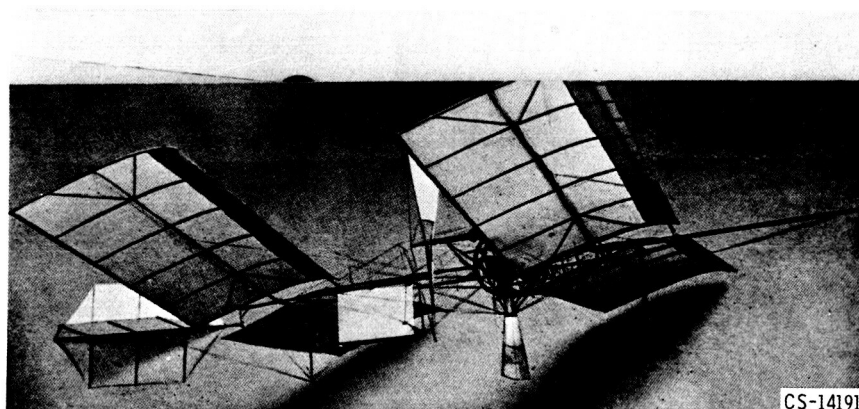
CS-42611

Figure 12. - Variable-sweep-wing Boeing Supersonic Transport. Design speed, Mach 2.7 or 1800 miles per hour.



CS-14188

Figure 3. - Otto Lilienthal (1894) at top and Octave Chanute (1896) at bottom.



CS-14191

Figure 4. - Professor Samuel P. Langley's Aerodrome.

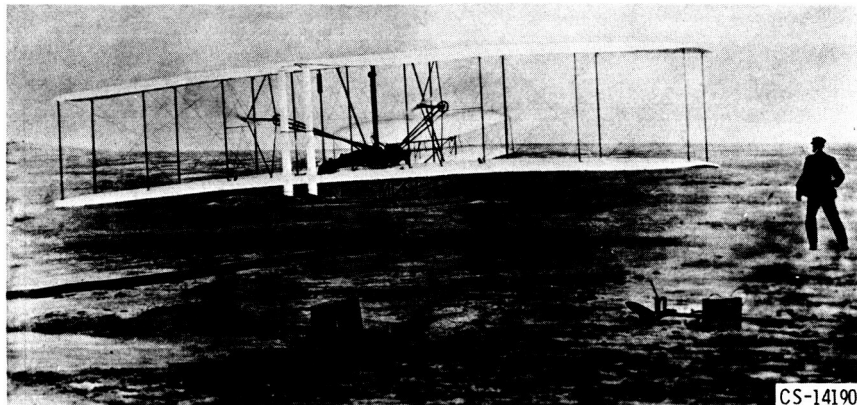


Figure 5. - Wright brothers' airplane (1903).

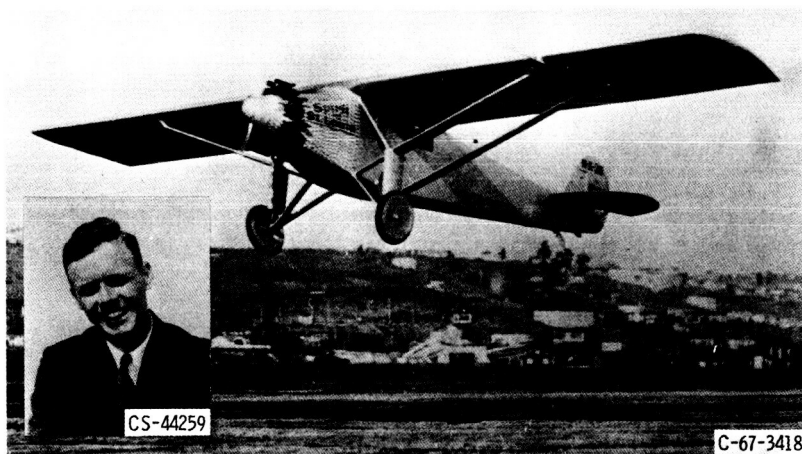
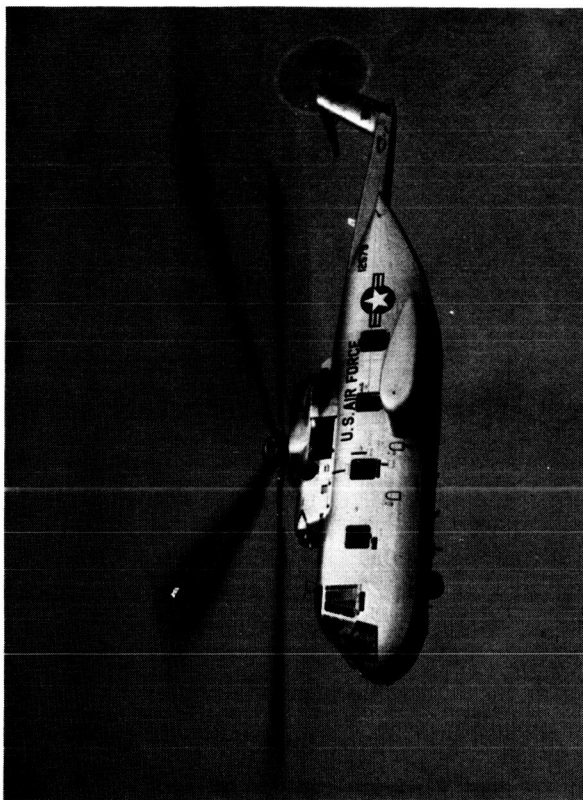


Figure 6. - Charles A. Lindbergh and his Ryan monoplane "The Spirit of St. Louis" that he flew in a solo nonstop flight across the Atlantic from New York to Paris in 1927. (Courtesy Smithsonian Institution.)



II-25. The CH-3C is powered by twin turbine engines and has a hydraulically operated rear loading deck and a 5000 payload capacity. It is amphibious.